U.S. DEPARTMENT OF COMMERCE
National Technical Information Service

PB-260 546

In-Process Pollution Abatement. Volume I Upgrading Metal - Finishing Facilities to Reduce Pollution

Environmental Protection Agency, Cincinnati, Ohio

Jul 73

BIBLIOGRAPHIC DATA SHEET	1. Report No. EPA/625/3-73/002-Vol-1	2.	3. Recipient's Accession No. PB-260 546
4. Title and Subtitle In-Process Pollution Abatement. Volume I. Upgrading Metal-Finishing Facilities to Reduce Pollution			5. Report Date Jul 73 6.
7. Author(s)			8. Performing Organization Rept. No.
9. Performing Organization Name and Address Environmental Protection Agency Cincinnati, Ohio Office of Technology Transfer			10. Project/Task/Work Unit No. 11. Contract/Grant No.
12. Sponsoring Organization Name and Address			13. Type of Report & Period Covered 14.

15. Supplementary Notes Also available from Environmental Protection Agency, Office of Technology Transfer, Cincinnati, Ohio 45268. See also Volume 2, PB-226 963. (PC A04/MF A01)

16. Abstracts

The first volume assists the metal finisher to understand where his pollution begins and how to reduce it and, having done so, to have a proper assemblage of facts so that his future endeavors at pollution control are not just self-servicing, but technologically sound and not inclined to obsolescence. In the second volume, water pollution and air pollution associated with metal-processing is evaluated and determinations made concerning feasible alternatives to wastewater treatment of metal-processing waste.

17. Key Words and Document Analysis. 17a. Descriptors

*Metal finishing,
*Industrial waste treatment,
*Water pollution control,
*Air pollution control,

Classification,
Chemical cleaning,
Acids,
Salts,
Chromates,
Process charting,
Surface hardening,
Upgrading,
Water conservation,
Ventilation,
Electroplating,
Coating processes.

17b. Identifiers/Open-Ended Terms

Metal finishing industry.

17c. COSATI Field/Group 11 F 13 B

18. Availability Statement National Technical Information Service Springfield, Virginia 22161	19. Security Class (This Report) UNCLASSIFIED	21. No. of Pages 73p
	20. Security Class (This Page) UNCLASSIFIED	22. Price 4.50/3.00

FORM NTIS-35 (REV. 10-73) ENDORSED BY ANSI AND UNESCO. THIS FORM MAY BE REPRODUCED USCOMM-DC 8265-P74

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA-625/ 3-73-002 - Vol.1	2.
3. RECIPIENT'S ACCESSION NO.	
4. TITLE AND SUBTITLE Upgrading Metal Finishing Facilities to Reduce Pollution -Volume 1	5. REPORT DATE Publication Date: July 1973
	6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S)	8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS Same as box #12	10. PROGRAM ELEMENT NO. 1HD622
	11. CONTRACT/GRANT NO.
12. SPONSORING AGENCY NAME AND ADDRESS U. S. Environmental Protection Agency Technology Transfer Cincinnati, Ohio 45268	13. TYPE OF REPORT AND PERIOD COVERED Technology Transfer
	14. SPONSORING AGENCY CODE EPA-ORD
15. SUPPLEMENTARY NOTES	

16. ABSTRACT

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a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Water Pollution Industrial Wastes Waste Water Metal-Finishing	Metal Finishing Wastes	

18. DISTRIBUTION STATEMENT PC also from Technology Transfer MF - NTIS	19. SECURITY CLASS (This Report) Unclassified	21. NO. OF PAGES 93
	20. SECURITY CLASS (This page) Unclassified	22. PRICE $4.50

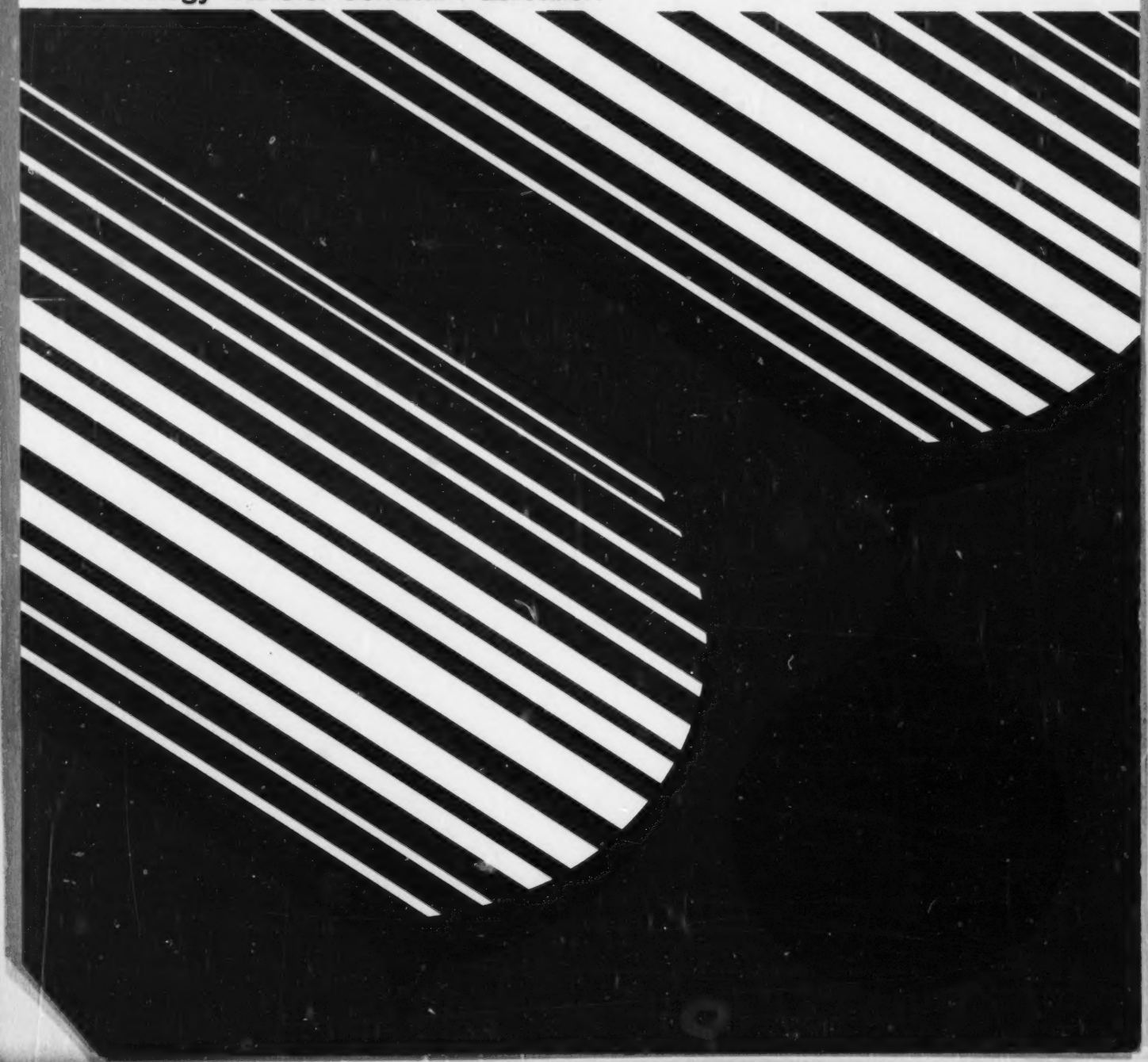
316018

In-Process Pollution Abatement

Upgrading Metal-Finishing Facilities to Reduce Pollution

PB 260 546

EPA Technology Transfer Seminar Publication



EPA - 625/3-73-002-Vol I

IN-PROCESS POLLUTION ABATEMENT

Upgrading Metal-Finishing Facilities to Reduce Pollution

ENVIRONMENTAL PROTECTION AGENCY • Technology Transfer

July 1973

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ACKNOWLEDGMENTS

This seminar publication contains materials prepared for the U.S. Environmental Protection Agency Technology Transfer Program and presented at industrial pollution-control seminars for the metal-finishing industry.

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Revised January 1974

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INTRODUCTION

The threat of air and water pollution to the welfare of the United States has been recognized only in recent years. The task of determining just how industrial wastes adversely alter the environment is still fraught with unknowns, because this work also has just begun.

Clear to the metal-finishing industry is the fact that its wastes are detrimental to the environment. The industry wonders about the *extent* of the detriment, the reasoning behind regulatory correctional measures, and the steps that industry must take to make permanent peace with the environment and still continue to use it.

This paper intends only to assist the metal finisher to understand where his pollution begins and how to reduce it, and, having done so, to have a proper assemblage of facts accumulated so that his future endeavors at pollution control are not just self-serving, but technologically sound and not inclined to obsolescence.

WHAT IS METAL FINISHING?

Metal finishing is used to improve the surface of a basic material by

- Cleaning it
- Hardening or softening it
- Smoothing or roughening it
- Depositing another metal on it by chemical exchange
- Electroplating another metal or series of metals on it
- Converting its surface by chemical deposition
- Coating it with organic materials
- Electrocoating it with organic materials
- Oxidizing by electrolysis

These processes are known more familiarly as cleaning and pickling, annealing, case hardening, polishing, buffing, immersion plating, electroplating, phosphating, conversion coating, oxidizing, painting, electropainting, and anodizing.

The corresponding changes produced by these methods of metal finishing on the basic material serve to enhance the value of the treated item by providing such improvements as

- Corrosion resistance
- Durability

- Esthetic appearance
- Electrical conductivity

Such processes also fill many special engineering requirements of industry such as stress relief, ductility, heat resistance, or the ability to stamp and form metal objects.

TYPE OF METAL FINISHERS

The metal-finishing industry may be considered in three segments: large captive shops, small captive shops, and job shops.

The large captive shop is usually a division of, or operated by, a major manufacturer whose product requires metal-finished items in quantity. These shops are to be found generally in the automotive and appliance industries and are noteworthy because of the size of their metal-finishing facilities and the magnitudes of their daily production and chemical consumption.

The small captive shops are usually minor adjuncts to their parent industries. Their roles are to supply metal-finished incidentals to the principal products. An example of this type of captive shop might be found in the machine-tool industry or in many of the sports equipment manufacturing companies.

Where large corporations find it impractical to maintain their own captive metal-finishing operations, the job shops serve as sources for satisfying their requirements for metal-finished parts.

The job shops exist solely on profits accrued from metal finishing. Jobs are accepted for metal finishing on contract, and the job-shop owner must be prepared to serve a variety of industries.

His role does not end with the finishing of his customer's wares. For survival, he is required to keep abreast of all changes in metal-finishing technology and his products' end-use requirements, thus serving his customers as supplier, inspector, and counsel—a role that the customers themselves are loathe to countenance technically or endure financially.

CHEMICALS AND BASIC MATERIALS USED IN THE METAL-FINISHING INDUSTRY

The list of chemicals shown in table 1 is not guaranteed to be comprehensive; it represents the great majority of potential pollutants with which we are concerned as we consider plant waste-control planning.

The types and quantities of materials and chemicals purchased furnish an excellent key to prediction of the process effluent characteristics. They also act as cross-checks on the accuracy of effluent analyses. An attempt has been made to indicate the expected environmental impacts of these materials when they become waterborne and airborne.

Table 1.—*Some chemicals used in the metal-finishing industry*

Chemical	pH adjustment required	Cyanide or chromium treatment required	Waste products[1]
Aluminum potassium sulfate	X		MS, DS
Aluminum silicate	X		MS, DS
Ammonium acetate	X		DS, NH_3
Ammonium bifluoride	X		MS, DS, NH_3
Ammonium chloride	X		DS, NH_3
Ammonium citrate	X		DS, NH_3, O
Ammonium hydroxide	X		DS, NH_3
Ammonium molybdate	X		MS, DS, NH_3
Ammonium nitrate	X		DS, NH_3
Ammonium sulfate	X		MS, DS, NH_3
Anisic aldehyde	X		O
Antimony potassium tartrate	X		MS, DS, O
Barium carbonate	X		MS
Barium sulfate	X		MS
Benzene (benzol)	X		O
Boric acid	X		DS
Cadmium cyanide		X	MS, DS
Cadmium sulfate	X		MS, DS
Calcium nitrate	X		DS
Chromic acid		X	MS, DS
Citric acid	X		DS, O
Cobalt carbonate	X		MS
Cobalt sulfate	X		MS, DS
Cupric sulfate	X		MS, DS
Diammonium phosphate	X		MS, DS, NH_3
Ferric nitrate	X		MS, DS
Fluoboric acid	X		MS, DS
Formaldehyde	X		O
Glue	X		O
Glycerine	X		O
Hydrazine sulfate	X		DS
Hydrochloric acid CP	X		DS
Hydrofluosilicic	X		MS, DS
Hydrogen peroxide	X		
Hydroxyacetic acid	X		DS, O
Hypophosphorus acid	X		MS, DS

[1]MS = metal sludge; NH_3 = ammonia; DS = dissolved solids; O = organic matter.

Table 1.–*Some chemicals used in the metal-finishing industry–Continued*

Chemical	pH adjustment required	Cyanide or chromium treatment required	Waste products[1]
Indium sulfate	X		MS, DS
Iron oxide	X		MS
Isopropanol	X		O
Lard oil	X		O
Lead fluoborate	X		MS, DS
Lead oxide	X		MS
Lime (calcium hydroxide)	X		MS
Magnesium sulfate	X		MS, DS
Manganese carbonate	X		MS
Manganese sulfate	X		MS, DS
Methanol	X		O
Monoammonium phosphate	X		MS, DS, NH_3
Nickel carbonate	X		MS
Nickel chloride	X		MS, DS
Nickel sulfate	X		MS, DS
Nickel sulfamate	X		MS, DS
Nitric acid	X		DS
Oxalic acid	X		MS, DS
Phosphorus acid	X		MS, DS
Potassium bromate	X		DS
Potassium citrate	X		DS, O
Potassium chloride	X		DS
Potassium copper cyanide		X	MS, DS
Potassium cyanide		X	MS, DS
Potassium ferricyanide		X	MS, DS
Potassium hydroxide	X		DS
Potassium phosphate	X		MS, DS
Potassium stannate	X		MS, DS
Potassium thiocyanate	X		DS
Sodium acid pyrophosphate	X		MS, DS
Soda ash (sodium carbonate)	X		DS
Sodium bicarbonate	X		DS
Sodium bisulfite	X		DS
Sodium bifluoride	X		MS, DS
Sodium citrate	X		DS, O
Sodium copper cyanide		X	MS, DS

[1]MS = metal sludge; NH_3 = ammonia; DS = dissolved solids; O = organic matter.

Table 1.—*Some chemicals used in the metal-finishing industry—Continued*

Chemical	pH adjustment required	Cyanide or chromium treatment required	Waste products[1]
Sodium cyanide		X	DS
Sodium dichromate		X	MS, DS
Sodium fluoborate	X		MS, DS
Sodium gluconate	X		DS
Sodium hexametaphosphate	X		MS, DS
Sodium hypophosphite	X		MS, DS
Sodium Hydrosulfite	X		DS
Sodium hydroxide (caustic soda)	X		DS
Sodium metasilicate	X		MS, DS
Sodium molybdate	X		MS, DS
Sodium nitrate	X		DS
Sodium orthosilicate	X		MS, DS
Sodium polysulfide	X		MS, DS
Sodium stannate	X		MS, DS
Sodium sulfate	X		DS
Sodium sulfide	X		MS, DS
Sodium sulfite	X		DS
Sodium tripolyphosphate	X		MS, DS
Stannous fluoborate	X		MS, DS
Stannous sulfate	X		MS, DS
Stearic acid	X		O
Sulfamic acid	X		DS
Sulfur (liquid)	X		MS
Sulfuric acid	X		MS, DS
Tallow glyceride	X		O
Tartaric acid	X		O
Tetrapotassium pyrophosphate	X		MS, DS
Tetrasodium pyrophosphate	X		MS, DS
Toluene (Toluol)	X		O
Trichlorethylene	X		O
Trichloroethane	X		O
Trisodium phosphate	X		MS, DS
Xylene (Xylol)	X		O
Zinc chloride	X		MS, DS
Zinc cyanide		X	MS, DS

[1]MS = metal sludge; NH_3 = ammonia; DS = dissolved solids; O = organic matter.

Chapter I

WATER-POLLUTION CONTROL

INTRODUCTION

This part of the paper identifies the in-process water-pollution-abatement techniques including the equipment available, reduction of chemical waste, planning to prevent pollution catastrophes, water conservation techniques, and a case study of the upgrading of in-process facilities to reduce pollution.

PROCESSING EQUIPMENT USED IN THE METAL-FINISHING INDUSTRY

It is not convenient to the scope of this report to discuss entirely the great diversity of equipment used in metal finishing. It is assumed that the reader needs no further description of the type of processing that is performed by hand through a great variety of tank-and-vat assemblies. Rather, it is hoped that the following scan of commonly used automated equipment will enlighten and also invite increased awareness of the difficulties to be met and resolved during the application of pollution-control technology and equipment to the metal-finishing facility.

As is seen in figures I-1 through I-8, the applicability of any of the automatic finishing machines is directly dependent upon the quantity of production required in a given length of time, the physical shape of the workpieces and the means by which they are to be fixtured for processing, and, of course, the nature of the metal finishing required. From workpieces so tiny that they may scarcely be observed by the eye to items weighing many tons apiece, all may be processed in variations of this basic line of equipment.

From the effluent-control standpoint, the type of machine chosen to be the most effective in fulfilling the desired production requirements will also have a marked effect on the nature of the effluent and the cost to handle it. For example, if a return-type automatic is to be selected, it is convenient and inexpensive to incorporate counterflow rinsing, because the rinse tanks are very small, handle only a rack or two at a time, and do not add a costly and lengthy enlargement to the prospective machine. Programed hoist equipment requires rinse tanks large enough to handle a *battery* of racks or a single rack of long parts. Incorporating more rinse tanks so that counterflow water-conservation tactics may be employed inevitably implies larger initial capital outlays. On the other hand, the motion of the hoist in transporting the work may be much more adaptable than the return-type automatic to delayed dwells in the "up" position, or to repeated dunkings of the work in the same rinse before moving on to the next process.

With existing equipment, any rearrangements that may lend themselves to chemicals and water-conservation techniques should also be closely considered for the effect they may have on

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- Cost to make the change
- Cycle reprograming
- Foundation updating
- Busswork and piping
- Ventilation
- Structural supports

SOME METHODS FOR REDUCING OR ELIMINATING CHEMICAL WASTE IN METAL FINISHING

Process Substitution

Wholesale substitution of low-concentration processes for those of high concentration or processes containing nontoxic materials for those containing toxic constituents has commenced only in recent years, inspired undoubtedly by the advent of pollution-control requirements. Unfortunately, the chemicals contained in the time-honored processes that made the greatest contribution to a profitable and efficient metal-finishing job were invariably the same chemicals causing the greatest adverse impacts to the environment as wastes in the plant effluents.

Substitution, therefore, became practical only when it did not compromise the quality of the metal finishing and was able to produce an environmental benefit. Perhaps the best known type of substitution in the past few years has involved cyanide-plating baths, principally those related to zinc. Elimination or reduction of cyanide was obtained by using noncyanide or low-cyanide-type processes. The noncyanide baths offered complete freedom from cyanide, but many of these processes employed chelating and sequestering addition agents to keep the zinc in a soluble form (one of the jobs formerly performed so well by the cyanide). Treatment of the resulting effluent hence became virtually impossible as no means was at hand to remove the equally undesirable zinc from the wastewater stream. Since cyanide was also a good cleaner, the first few minutes of dwell time in the cyanide-plating bath were cheerfully accepted as cleaning time to complete the job only perfunctorily performed by the previous cleaning and pickling cycle. Without any cyanide, substantial improvements were required in the preplating treatment steps to achieve good metal-finishing quality. Many different types of noncyanide processes are now available. Applicability of these processes must be weighed with due consideration of effluent improvement and process-operational changes.

The low-cyanide processing solutions obviously do not offer complete relief from the onus of cyanide in the effluent, but they can account for a substantial reduction in use (90 percent is achievable) and an equally substantial improvement in effluent quality. These baths are not really substitutes, but dilute versions of the baths they "replace." Tighter process control generally is required when these baths replace conventional cyanide processes, but the use of chelates may be avoided and the zinc disposal problem may become solvable.

Other substitutes have found use in the industry. They are

- Nonphosphate cleaners
- Non-chromium-bearing dips (in conversion coatings and anodizing)

- Noncyanide stripping solutions
- Non-chromium-bearing bactericides for cooling waters
- Noncyanide gold and copper processes

Some guideline questions should always be considered when substitution is contemplated.

- Will I eliminate one effluent problem and create another?
- Do I understand fully the control problems that might accompany the change?
- Have I sufficient man-hours available to handle tighter control requirements?
- Will the substitution affect in any way the final quality of my product?
- May I expect an increase in cost in my operation, or will I experience a saving?
- If I already have a waste-treatment facility, what effect will the substitution have on the treatment system when it is mixed with my normal waste flows?
- Did I overlook any unforeseen ventilation or Occupational Safety and Health Act-related problem?
- Have I calculated the cost of changing my equipment to accept the substitute process?

Process Solution Concentration—Minimum Limits

Most processes offer a range of concentrations in which they may be operated successfully. The industry traditionally has selected the midpoint in these ranges as the operating concentration. With effluent standards and cost savings in mind, serious consideration should be applied to operating the process solutions at their minimum concentrational limits. As an example, a standard nickel-plating solution has the following composition limits:

Chemical	Range	Operating concentration
Nickel sulfate ($NiSO_4.6H_2O$)	40-50 oz/gal	45 oz/gal
Nickel chloride ($NiCl_2.6H_2O$)	8-12 oz/gal	10 oz/gal
Boric acid (H_3BO_3)	6.0-6.5 oz/gal	6.3 oz/gal

At the above operating concentrations, a typical small plating shop running an average of 12 hours per day and 250 days per year would experience an annual loss of nickel salts (due to dragout) of approximately 8,500 pounds nickel sulfate and 1,900 pounds nickel chloride (based on the processing of 600 square feet per hour and a conservative dragout rate of 1.5 gallons per 1,000 square feet). Had minimum concentrations been used for the year, the resultant saving in nickel salts would have been 950 pounds nickel sulfate and 375 pounds nickel chloride, or a saving of about $800. If this shop applied the same thinking to the other process solutions in the plating line, a major improvement in operating costs would be readily obtainable. Not considered in the improvement is the potential cost savings in effluent treatment. All metal-finishing operations merit this type of assessment.

If minimum concentration limits become the practice, tighter process control should be expected and accommodated. Likewise, any possibility of a reduction in product quality due to mediocre process performance should be evaluated.

Control of Dragout

"Dragout" is defined by Kushner[1] as "the volume of solution carried over the edge of a process tank by an emerging piece of work." There are several factors that influence the rate of dragout. They are

- Velocity of withdrawal of the workpieces
- The geometry of the workpieces
- The positioning of the pieces on the rack or fixture
- The drainage time allowed over the process tank
- The viscosity and density of the process solution
- The temperature of the solution

Many devices may be used successfully for dragout reduction. The velocity of withdrawal of work from the process tank is least controllable when the metal-finishing cycle is operated by hand, owing to human fatigue. An excellent method of circumventing this obstacle is to place a bar or rail above the process tank where the rack may be suspended for drainage while its predecessor is removed from the rail and transported to the next phase of the finishing cycle. If, however, the equipment is automated, withdrawal may frequently be slowed, without a subsequent loss of production, by reorganizing machine motion. (Vendors of metal-finishing machines can assist on these motion studies.) No standard rule is available to predict accurately the amount of dragout volume to be saved by a given reduction in withdrawal speed; noteworthy only is that a saving may be expected, the degree to be determined by the specific application.

When the purchase of new equipment is being considered, withdrawal and drainage times should merit close attention before a final design is chosen. This consideration is especially important when related to bulk processing or barrel plating. Slow barrel rotation during withdrawal has reduced dragout volumes by as much as 50 percent. Machines may be automated readily to accommodate this type of rotation at the time of design.

In general, as the chemical content of a solution is increased, its viscosity increases, resulting in a thickening of the film clinging to work withdrawn from the process solution. This increase contributes not only to a larger *volume* of dragout, but to more chemical waste in that volume and increased difficulty with subsequent rinsing.

Temperature also has an effect on dragout. Elevating the operating temperature of a process solution will result in diminished dragout by reducing viscosity. Care must be exercised, when increasing temperatures, that bath performance remains unimpaired and that the workpieces acquire no adverse surface conditions such as dry-on patterns.

A dilemma historically plaguing the metal finisher, especially in electroplating, has always been the positioning of workpieces on a rack. The primary consideration in racking is proper exposure of the work to the anodes so that the coverage and thickness uniformity of the electrodeposit may

be optimum. Drainage and rinsability figure in the racking deliberations because of possible damage to the workpiece surface by insufficient or inefficient rinsing, or to succeeding process solutions by drag-in of unremoved chemicals from the previous solution. A contemporary consideration of chemical waste is now made more critical by potential effluent treatment costs. There is even the possibility that the reduction of this waste (and its attendant effluent purification costs) may in some cases make acceptable the incipient difficulties of poorer coverage and plate distribution.

Maintenance of racks, fixtures, and rack coatings, as an industry average, has been generally poor. Transport of chemicals from one process to others underneath loose-rack coatings is not uncommon. Chromium-bearing solutions, for example, appearing in plant effluents in spite of treatment systems designed to handle the normal chromium discharge sources, have been traced to rinse tanks and process solutions remotely located from the chromium discharge points, having arrived in these areas by the loose-rack coating route. Increased attention to rack maintenance not only will eliminate this potential hazard; it is certain to contribute to a welcome reduction in the numbers of workpieces rejected because of poor contact.

Kushner[1] has summarized dragout loss reduction principles with 10 rules.

1. Keep the concentrations of all dissolved materials at the minimum value requisite to the proper operation of the bath.
2. Do not add anything to a plating bath that does not perform a necessary function in the same.
3. Operate the plating bath as hot as possible.
4. If there is a choice of conducting salts that can be used in a plating bath, use the salts that give the greatest density and the smallest viscosity per unit concentration.
5. Make use of an effective wetting agent in the plating bath.
6. With a given, fixed time period allowed for withdrawal and drainage, use the largest part of the period for withdrawal.
7. For minimum dragout, rack solid objects so that they are extended in area rather than in depth.
8. Do not rack objects directly above each other so as to lengthen the drainage path.
9. Tilt all solid objects with plane or singly curved surfaces so that drainage flow is consolidated.
10. Every solid object, outside of a sphere, has at least one position in which dragout will be at a minimum.

Significant chemical losses are also encountered in connection with the batch purifications of process solutions in external storage tanks and the repacking of process filter equipment. Process liquids entrapped in sludges and in discarded filter packs are recoverable by the simple expedient of flushing with water and returning the water, properly filtered, back to the process to replace evaporation losses. Such a practice becomes doubly valuable when the eventual disposal of the sludges remaining after purification is considered, as the presence of soluble metals or other toxic materials in these residues, by today's standards, is forbidden generally by regulations for the disposal of solid wastes to landfill sites.

PLANNING TO PREVENT POLLUTION CATASTROPHES

There is, of course, a great difference between the type of pollution that causes a nuisance to the public domain by gradually altering the environment to which it has been discharged, and a catastrophic pollution that causes not only a sudden and far-reaching change in the environment, but also poses a direct and immediate threat to the health of aquatic life and humans.

In the metal-finishing plant, nuisance pollution is characterized by the daily flow of waste rinse waters to the sewer, usually coupled with small-volume spillages incurred in workpiece transport between processes or during the addition of maintenance chemicals to the processes themselves. Spent process solutions *gradually* discharged along with waste rinse waters may also be considered nuisance pollution.

On the other hand, process solutions, containing concentrated toxic materials, discharged suddenly and in large volume to the sewer, constitute potential catastrophic pollution. When these discharges are deliberate, they result from human carelessness and error, and may be eliminated only by stringent in-plant housekeeping measures. Electromechanical devices strategically located within the plumbing system may sense the passage of such discharges, but serve only to inform of the damaging event after its occurrence.

Accidental discharges of a catastrophic nature are far more insidious because they are not predictable. Fortunately, they are very rare in this industry.

Although revision of a plant to prevent both nuisance and catastrophic pollution is more properly the province of the pollution-control systems-design engineer, as it is an integral portion of his entire prospective treatment scheme, control measures should be at least evaluated by the plant operator before design discussion. Such evaluations may forestall delays and interruptions of the operator's work schedule that otherwise may be caused by the installation of the treatment systems.

Several general plans may apply as temporary catastrophic-pollution-prevention techniques, as follows:

1. All rinse waters are *piped* directly to the sewer (with plans to pipe these rinse waters to their respective treatment plant areas once the waste-treatment system is designed and installed). Thus, all floor exits to the sewer may be plugged, preventing the escape of accidental spills of concentrated solutions. Spent process solutions in this system are pumped to holding tanks for removal by scavenger, or for treatment and gradual discharge. Floor sumps will be required for sump pumps. Obviously, where both cyanide and chromium solutions are in use, steps must be taken in floor segregation to assure that cyanide and alkali-spent solutions are prevented from mixing with chromium and acid wastes, thus avoiding the possibility of generating toxic hydrocyanic acid gases. Separate drainage, sumps, and holding tanks would be provided for this condition.

2. Another method is to install a large holding pit or lined lagoon located outside. All flows exiting from the plant would pass through this pit or lagoon before entering the sewer. Electromechanical devices for the measurement of pH and conductivity would be installed before the holding area. Any sudden and large variations in pH or conductivity sensed by the instruments would sound an alarm and turn off all incoming water to the processing plant. The retention time in the pit or lagoon would be sufficient to cushion and absorb the incoming concentrated solution, or "slug," without adverse effect at the outfall. Thus, the slug would be retained in the holding facility for treatment or disposition.

3. A third means of attack is based on the supposition that the plant in question has existing floor trenches through which all wastes are conveyed from the plant, and that these trenches are large enough to be divided lengthwise into two subtrenches. By this dividing technique, the outer side of the trench could be used for rinse waters. The headers from the rinse-water tanks could go directly to this portion of the trench, which would then be covered over to prevent entry of floor spillage. The other half of the trench would remain open and would be used as in plan 2, i.e., it would end in a sump. Accordingly, this open portion of the trench would have no exit to sewer, and would catch all solution dumps and floor spills for pumping to a disposition point elsewhere.

To increase awareness of potential pollutive sources within the plant, the following suggestions for an investigative effort are made:

- Begin by tracking all plant incoming water from its sources to its ultimate destination.
- Do not overlook fume scrubbers, water-cooled rectifiers, heat exchangers, boilers, heating and cooling coils, air conditioners, and welders.
- Ascertain that all inlet waterlines to process solutions have antisiphon devices.
- Inspect all heating and cooling coils for physical condition. (Conductivity meters for leak detection will be required when a waste-treatment system is installed.)
- Thoroughly inspect all floors and foundations in the processing areas for possible leakage and consequent percolation to ground waters.
- Check all chemical storage areas for compliance with safety regulations and methods for handling "empty" and broken containers.
- Make an inspection inside and out of *all* process tanks and filters for physical condition. Check especially those tanks where processes are seldom, if ever, removed. All piping should also be examined.
- Record all data acquired with the foregoing steps. They will prove very useful later.

WATER-CONSERVATION TECHNIQUES

Rinsing represents the most frequently used process in metal finishing. It is by far the largest consumer of water, and has been given little or no consideration as a cost or problem area. Abundance, ready availability, and low cost historically have contributed to this inattention to plant water use and to good rinsing practices. Hardening this attitude has been the absence of any strictly enforced restrictions on the discharge of waste rinse waters. Rinsing difficulties could always be overcome with more water—where the water went afterward was a matter of no import. But today the environment commands attention. Water use and effluent-water quality thus have become major factors in profit-and-loss statements, and are the principal determinants of the magnitudes of capital expenditures for water-pollution-control systems.

Modern effluent regulations have eliminated any remaining possibility of continuing to discharge untreated water. Open to question only are the nature and degree of treatment that will be required. Of great economic consequence, therefore, is any reduction in water use that may be

achieved through plant reorganization of rinsing practices. In plants where there has been little attention to rinse-flow rates, water-conservation studies have repeatedly shown that *each* rinse-tank flow usually may be reduced by *50 percent* or more without impairment of rinsability. (In one large plant, a flow of 10,000 gal/hr was reduced to 700 gal/hr before rejected work attributable to poor rinsing was detected.)

The objective of rinsing is to flush away and remove dissolved salts and solids clinging to workpieces so that

- Coatings subsequently applied will bond properly to the work.
- No unwelcome discoloration or chemical change will occur to the work surface due to residual films.
- Contamination of succeeding process solutions may be prevented.

The objective in water conservation is to get the maximum amount of rinsing with the least amount of water. Rinsing occurs at the work surface and is influenced by

- Exposure time of the workpieces to the water
- The amount of "fresh" water that may be brought to the work surface during the exposure time
- The temperature of the entering workpieces and the temperature of the rinse water
- The shape of the work and its position on the rack or in the fixture

Rinse water removes chemical films from workpieces by the process of diffusion. The rate at which the film is removed is dependent upon the water solubility of the chemicals in that film. The chemicals are thus absorbed into the body of the rinse water. From a practical standpoint, there are a number of methods available (although, inexplicably, seldom used) to improve diffusion and hasten the completion of the rinsing process. Many of these methods also produce a dramatic reduction in water use.

The most difficult part of the water conservation is the first step, the determination of minimum water use for each rinse phase of the metal-finishing cycle. "Minimum water requirements" cannot be based on the supposition that the workpieces must be *completely free* of any chemical films, for the amount of water to produce such workpiece surfaces is so great as to be economically untenable and probably unavailable. In actual practice, a chemical film will almost always remain on the work after rinsing. The amount of film that safely may be allowed to remain on the work is based on two considerations:

- Chemical films remaining after rinsing must not poison the succeeding process to which the workpieces will be exposed.
- These postrinsing chemical films must not produce adverse effects on the workpiece surfaces themselves, or cause underlying problems for subsequent coatings to be applied on the work.

In short, one must reduce rinse-water flow until the residual chemical film, because of its concentration and/or thickness, begins to cause subsequent production problems.

Implicit to these considerations is the fact that each process and each plant is different; production, work geometry, incoming water quality, processing equipment configuration, even the

protective coatings on incoming basic materials and storage practices, all will influence water requirements. Therefore, each plant operator will be obliged to determine his own minimum water requirements step by step and rinse by rinse. A logical approach might include the following steps:

Step 1

Investigate plant chemical-consumption records. Peak periods of chemical additions to process tanks and a rundown on parts that were metal finished during these peak periods will help to locate the work producing the most dragout.

Step 2

When this work is being run, select a rinse tank following a process whose solution is known to be difficult to rinse. (Chromium or cyanide baths are good examples.) The rinse tank must have been cleaned and filled with fresh water and then turned off. The level should be high enough to allow immersion of the rack or barrel to the usual depth, but should be low enough to prevent water displaced by the immersion to overflow. Vigorous agitation of the work and/or the rinse water is suggested. With the volume of water known by simple tank measurement, and with an analysis of the process bath preceding the rinse already available, an analysis of one process bath constituent in the rinse water predicts all the other constituents by ratio and establishes a highest dragout-volume figure. This figure may be assumed to be the dragout volume from each of the rest of the metal-finishing processes in the cycle where the same racks or barrels are used. Although it is recognized that 100-percent removal of the chemical film may not always be removed in this single stagnant rinse, the operator may exercise his own judgment on the efficiency of a *second* stagnant rinse for dragout determination. A hose might be used (as a second rinsing) as the work is being withdrawn, and the used water collected, measured for volume, and analyzed as before.

Step 3

When the *volume* of dragout has been thus established, its concentrations in the case of every process bath should be arithmetically adjusted to the highest levels at which any of these baths might be operated. A similar dragout determination should be considered wherever a different line is involved and the work processing motions and fixtures are likewise different. (Dragout figures thus achieved are of paramount importance in the successful design of waste-treatment systems.)

Step 4

With the dragout concentrations and volumes now known, reduction of water use in rinse tanks may commence. Existing rinse-water flows must be measured. In the absence of flowmeters, two techniques may be used successfully.

The first method involves physical measurement of the working volume of the rinse tank, a lowering of the rinse-water level to a measured depth (at the end of the working day after the water has been turned off) and a measure (at the beginning of the next day when the water is turned on again) of how long it takes to fill the tank again to operating level. This method is effective when rinse-tank outlet headers are permanently piped into the exit trench or sewer. A variation of this method is to insert a 5-gallon bucket into the *flowing* rinse. By withdrawing 5 gallons of rinse water rapidly, one may time the period required for 5 more gallons of rinse water in the rinse tank to reach overflow levels again. This test must be repeated several times and the results averaged, because it

is difficult to ascertain visually the exact time at which the flow over the overflow dam has reached a stabilized flow condition.

The second method involves a 5-gallon bucket and a stopwatch for measurements at the overflow outlet. An alternative method is to buy a flowmeter and use it in each of the incoming rinse-water lines, one by one, until the necessary information is obtained.

All flow-rate measurements should be recorded carefully, as should readings at the water main. Now the actual reduction of rinse flows may begin. This is the most difficult phase of the entire conservation and abatement operation. It is laborious, because each rinse must be carefully observed during the gradual day-to-day reduction in flow rate so that the effect on the work and/or the succeeding process may be duly noted as the moment arrives when poor rinsing begins to cause rejections. The strictest discipline must be maintained in the plant by the operating personnel so that the cause for rejection may be traced to its true source. Valve settings on rinse-water lines must be under the specific control of the person charged with water conservation, and tampering should not be tolerated. As the maximum reduction in flow rate for each rinse is revealed and the readings recorded, rinse-water flows may be advanced slightly to prevent further rejection. At this juncture, if no further conservation measures are to be considered, flow-restrictor valves should be installed in all rinse-tank incoming waterlines. Several types are available that not only restrict water flow to a fixed maximum output, but also will adjust automatically to changes in water main pressure, even act simultaneously as siphon breakers, and are tamperproof. Flowmeters may be used in conjunction with normal valving to control flow, having the advantage of advancing flow rates when desired, but they are not tamperproof and are much more expensive. It should be duly noted that up to the point of installing valves or meters, *no money* has been spent except in the necessary labor. It is also likely that the average plant, upon concluding this first water-conservation effort, will achieve a reduction of about 50 percent in its water use. An average plant with a total flow rate of 100 gal/min can thus save approximately 50 gal/min, and, based on 3,000 operating hours per year and a water charge of 25 cents per 1,000 gallons, an annual saving of over $2,000 is achieved. The same reduction in water use will cut the capital costs of a waste-treatment system in half—for the average plant, that saving can amount to $40,000.

Further and equally dramatic reductions in water consumption are achievable through the use of mechanical devices and equipment rearrangements, such as the following.

Counterflow Multiple-Tank Rinsing (Figs. I-9 and I-10). In counterflow rinsing, used water exiting the first tank becomes feed water for the second, and after being used again, feeds the third tank, and so on.

The advantage of counterflow rinsing is in the repeated exposure of the workpieces to the water, the increase in dwell time (permitting more diffusion to occur), and the ability to bring most of the water passing through into more intimate contact with the work. The results in water saving are gratifying. For example, if a dragout of 1 gal/hr in a given case required a 1,000-to-1 dilution in order to produce acceptable work, 1,000 gallons of rinse water per hour would be required in a single rinse tank; in a double counterflow rinse system, 30-35 gal/hr are required, and in a triple counterflow rinse system, 8-12 gal/hr are needed. The disadvantage is that the work requires two or three processing steps instead of one, and more equipment and space is also mandatory. If multiple counterflow rinsing is designed into prospective automatic metal-finishing equipment, the initial disadvantages are increased capital expense and space requirements. The ultimate advantage lies not only in the enormous drop in water costs, but also in a sharp reduction in the cost of the supporting waste-treatment system. Additionally, the curtailment of water volume makes the use of waste recovery systems more inviting.

Multiple-Tank Rinsing (Fig. I-11). This type of rinsing is merely a battery of single rinses, each with its own feed waters. The principles are generally the same as in counterflow multiple-tank

rinsing, although the total reduction in water consumption will not be as great as with the counter-flow system.

Spray Rinsing (Fig. I-12). Two categories of spray rinsing may be used. The first, impact spraying, uses both impact and diffusion to remove contaminant films. It uses little water compared to immersion rinsing, and may be used in some cases as a recovery rinse by pumping the collected spray volume into the previous process tank, but is disadvantaged when the workpieces have areas inaccessible to the spray nozzles.

The second method, rinse and spray, employs immersion rinsing followed by a spray operational only when the work is withdrawn from the rinse tank. It is advantageous in removing stubborn films by impact and permits lower water flows in the main body of the rinse tank.

Fog Rinsing (Fig. I-13). Fog rinsing finds utility at exit stations of process tanks. A fine fog is sprayed on the work, thus diluting the dragout film and causing a runback into the process solution. Fog rinsing finds application in those instances where process operating temperatures, high enough to produce a high evaporation rate, allow replacement water to be added to the process in this manner. Fog rinsing also prevents dry-on patterns by cooling the workpieces. To be effective, fog rinsing requires a slow rate of withdrawal of the work from the process tank.

Chemical Rinsing (Figs. I-14 and I-15). The principle of chemical rinsing has been used by the metal-finishing industry for many years. One of the oldest applications of this principle was used quite effectively to eliminate staining from the chromium solution, notoriously difficult to rinse. By the simple expedient of making the first rinse after chromium plate a stagnant rinse containing sodium bisulfite, the drag-in of hexavalent chromium was converted to trivalent chromium. Thus, the rinsability of the work in the second rinse was improved considerably by:

- Changing the chemical nature of the film on the work in the stagnant rinse, and
- Reducing film concentrations before attempting to rinse by diffusion. The same principle is frequently employed in "neutralizing" dips.

The application of chemical rinsing to plant effluent treatment has been well described by Lancy[2, 3, 4] and Pinner[5] and is known as "integrated waste treatment" in the industry. Aside from the environmental benefits thus achieved, this type of chemical rinsing also prevents the majority of heavy metal solids formed in the chemical rinse from reaching the succeeding water rinses by removing these materials in an external settling vessel. This is accomplished by flowing the chemical rinse solution to a treatment reservoir. The overflow from the reservoir is pumped back to the rinse tanks forming a complete closed-loop system. Chemicals are added to the reservoir to provide a controlled excess of reagent in the solution. The reservoir acts as a combined reaction and settling tank. Because of the presence of a controlled excess of reagents in the chemical rinse tank, toxic materials and heavy metals are removed from the metal-finishing sequence and are prevented from entering the subsequent water rinse. At the same time rinsing is improved due to the fact that the diffusion layer, which is present during conventional water rinsing, is broken down by the chemical reaction.

Some Additional Techniques

Such equipment rearrangements and additions as water-conservation measures are capable of reductions in water use of up to 90 percent! Additionally, the savings related to prospective capital outlays cannot be calculated solely in terms of reduction in equipment size; it can make the difference between satisfying effluent-control demands or closing the metal-finishing plant, if considered only from the standpoint of available plant space. The basis for future effluent-control systems design, likewise, may be radically changed by the skillful application of conservation techniques.

Other devices that assist in the improvement of rinsing are

- Agitation of the work in the rinse tank
- Air agitation of the rinse water
- Hydraulic agitation of the rinse water
- Agitation through mixers or impellers
- Ultrasonic agitation
- Elevation of rinse-water temperature
- Use of rinse aids and wetting agents
- Recirculation and reuse of rinse water using ion exchange

No consideration has been given here to the possibilities of reusing treated water from a prospective effluent-treatment facility to achieve yet a further reduction in water purchases. An accurate assessment of the volume and quality of reuse water from this source cannot be made until the design concept for a treatment system has been decided. The treatment methods chosen will determine the quality of the treated water and the selection of rinse tanks where it may be safely used. Nonetheless, the prospect of recovered water must be considered as a factor during water-conservation planning endeavors.

When the foregoing water-conservation practices have been concluded, the compiled data will supply the necessary ingredients to predict rinse-water volumes required when the new workpieces and racking produce a change in dragout conditions. Only the *new* dragout volume and concentration need be determined by actual analysis (as defined earlier in this presentation). Formulas[6, 7, 8] may then be applied to calculate the flow rate required, and the proper restrictor valve settings may then be applied.

UPDATING METAL FINISHING AND POLLUTION CONTROL AT COMPANY X

At a meeting of the board of directors of Company X on October 18, 1971, the major topic of discussion was pollution control and what to do about it. Everyone agreed that something should be done, but since very little pressure had been received by Company X from the people down at the sewage works to clean up the company's discharges (and besides, there were no clear rules or recommendations to date that pointed the way to doing a once-and-for-all job on pollution control), there was an understandable reluctance to spend money when the goal was not clear and it did not make a profit.

The conclusion of the board on that day was that it would be necessary to appoint a responsible member of middle management to the task of finding out what the scope of the problem was, and, then, how it could reduce the amount of pollution and get ready, once the oncoming regulations applying to them became known, to put in pollution-control systems. If, at the same time, a way could be found to reduce the waste of the company's chemicals and water, so much the better.

To accomplish these objectives quickly and expeditiously, the board selected an aggressive young manager. His primary responsibility was to define the plant's environmental problem—if time remained to perform his other duties, fine—if not, those duties would be assigned to someone else. In addition, he was told that all future environmental considerations affecting the operations of Company X would be his responsibility. In effect, he became the new pollution control officer reporting directly to the president and chairman of the board. He was given the authority to require the cooperation of all plant personnel to accomplish his mission.

The first step was to develop a site plan (see fig. I-16) to show

- Where the waterborne wastes came from and where they were going
- Where the plant boundaries were
- What usable space was available for future pollution-control equipment
- What influence the topography might have on drainage

Several more points were revealed during the site investigation.

- There was no manhole at the point where the plant industrial sewer joined the interceptor, and thus, no easy way to sample the effluent for analysis or to determine the flow rate. A design for a manhole was obtained from the city sanitary department; it included a calibrated V-notch weir and provisions for monitoring equipment.
- It was possible during a rain to have drainage from a chemical storage area for "empty" containers run into a ditch leading to a small creek.
- The water table at the outside area assigned to future pollution control equipment was more than 30 feet down.

Next came a sketch and study of the equipment layout (see fig. I-17), which included

- The location of each waste-producing piece of equipment
- The processing cycles
- The production from each cycle
- The location of accessory equipment

The geography of the equipment would prove useful when the time came to move pollution-control equipment into the plant. Updating of this layout print whenever any equipment changes occurred would prevent the appearance of an obstacle (where no obstacle was supposed to be) to confound the installation engineer. (The importance of this document to a pollution-control systems design engineer is incalculable; it has a major influence on the selection of both treatment concept and equipment.) Recorded also at this time was information concerning

- Plant electrical power and capacity
- Steam availability

- Head space and usability
- Support column locations

Since four major metal-finishing lines were to be examined, it was decided to look at them one at a time. Hence, an individual equipment layout was drawn in each case. The nickel-chromium plater (see fig. I-18)—including its rack strip line—began the parade. The object was to determine and record what was in each process tank in terms of major chemical constituents, when spent processes were dumped, how much rinse water was being used, and what volume of dragout was being developed. To accomplish the first, a record of purchases of all chemicals and basic materials for 1971 was obtained from the chief buyer, and matched with the metal-finishing department's record of additions to the various tanks. Where proprietary materials were involved, the suppliers of those materials were contacted for information on the principal ingredients.

Next came the determination of dragout and process dumping schedules (see fig. I-19). In this line, the chromium-plating solution was chosen for the measurement and used as the criterion for the other process dragout volumes in the line. No substitutions were contemplated, but plans were made to investigate the applicability of phosphate-free cleaners. All processes were reduced to their minimum concentrations, and a fog rinse was installed at the exit station of the nickel bath.

Attention now turned to the rinse flows (see fig. I-20). Gradual reduction of these flows over a period of 5 weeks produced an average cutback for the entire line of 910 gal/hr, or approximately 55 percent.

In the zinc plater (see figs. I-21 through I-23) the same procedure was used. The cyanide zinc solution was replaced with a noncyanide, nonchelated alkaline zinc process, and the chromates were made to last 50 percent longer by altering the baths with inhibitors and increasing updwell time over them. Double dunking is now being considered in selected rinses.

Rinse-flow reduction amounted to an aggregate of 1,400 gal/hr, or about 45 percent.

The phosphater (see figs. I-24 through I-26) did not have any substitution of process. Rinse-water flow was reduced by 750 gal/hr, or about 40 percent. It was discovered that the cleaners would last for 10 days if small frequent additions of replenishment cleaner were made. This practice resulted in a 50-percent saving by decreasing the frequency of the discard of spent process.

Only a small saving was realized in the anodizer (see figs. I-27 through I-29). The desmutter was replaced by a chromium-free process, and a reduction in water use of 80 gal/hr, or about 35 percent, was realized.

After the rinse-water conservation program was completed, several remedial measures were taken to prevent the new housekeeping attitude from having a relapse.

- All incoming rinse-water lines were equipped with restrictor valves.
- All hoses were spring loaded so that they could not be abandoned in a running condition.
- All the rinse-water mains leading to each automated line were equipped with solenoid valves connected to the control panels of each machine. When the machines were not operating during breaks or lunch periods, the valves automatically shut off rinse-water flow.
- An investigation is now being carried out to determine the advisability of conductivity cells for the rinse tanks.

- Areas between adjacent tanks (where spillage and drippage from work in transfer could fall to the floor) were equipped with troughs to catch such drippage and let it drain back to the process from which it had originated.

- All naked anode rails were taped to prevent erosion of contaminating metals into the processes they served.

- Tank covers furnished with original equipment, and long since removed from the tanks, were returned to their intended purpose.

- Chemical definitions of all protective oils or drawing and stamping compounds used either in the plant or by vendors were obtained, tested for ease of removal, and catalogued. Vendors and plant personnel alike were expressly forbidden to change the composition of any of these coatings without notifying the plant chemist and the pollution-control group. Similarly, changes in metal-finishing process compositions could not be made without approval by the pollution-control group.

Company X, in the first year of operation since these changes were made, has saved:

	Amount
By lowering water use	$ 4,300
By reducing chemical use	5,800
By a 1.7-percent drop in overall rejection rate	7,700
Total	$17,800

What is more important, Company X had only a few more chores to perform and it would be ready for pollution-control design. A foundation plan (see fig. I-30) was needed so that a design engineer could make recommendations on the segregation of accidental spills and on the most convenient disposition of spent processes. The problem of catastrophe prevention would require a long look at the types of coatings available for floor and foundation protection. Although Company X had never experienced a catastrophic spill in its 17 years of operation, it was painfully evident to the board of directors that the existing foundation plan did not offer safety, should the 17-year record be ended inadvertently. (And, too, the city had just received funds to erect a secondary treatment system, complete with bugs that eat sewage but do not much like metal-finishing wastes.) The foundation plan, however, did lend itself to the temporary piping of all rinse waters to the underground pipes leading to the interceptor. Thus, the trenches could house the rinse-water pipes and also be used to convey floor spills and dumps to blind sumps from which they would be pumped into holding tanks for disposition. This plan is now being implemented by Company X.

All that now remained was to tabulate each toxic material (see table I-1) by reviewing materials purchased and process composition. The tabulation accurately predicts the quality of the effluent. With the new manhole now installed, Company X is recording flow rates exiting from the plant. Composite samples are being taken by means of a 24-hour sampler recently purchased. Quantitative results will soon be available. Because Company X took the time to survey its plant and its chemical use, the need for extensive and expensive effluent sampling has been greatly reduced. Effluent sampling will confirm by analysis the accuracy of the earlier dragout determinations. The record on the contents of each process and Company X's purchases will tell the analyst what he must search for in the samples.

Table I-1.—*Items to be expected in plant effluent of Company X*

Metals	Organics	Dissolved solids
Nickel	Soluble oils	Calcium
Chromium	Immiscible oils	Sodium
Copper	Gluconates	Potassium
Iron	Dyes	Borates
Antimony	Proprietary additives	Carbonates
Aluminum		Nitrates
Lead		Chlorides
Zinc		Sulfates
		Fluorides
		Silicates
		Phosphates

The company has now turned its attentions to developments in environmental regulations. Plans for company growth will be influenced, but Company X now has bought the time to weigh these plans carefully, the time to examine the field for firms whose capabilities in environmental control design will conclude successfully the work it has started. Company X is also satisfied that when the control system it chooses is installed, it will be able to accommodate the work without any serious interruption in normal production.

Company X reckons that it has spent almost $6,000 in man-hours, analysis, and some equipment. It has discovered many serious lapses in production techniques during the investigation. It has eliminated any reasonable possibility of catastrophic pollution. Most of all, Company X is ready for the future.

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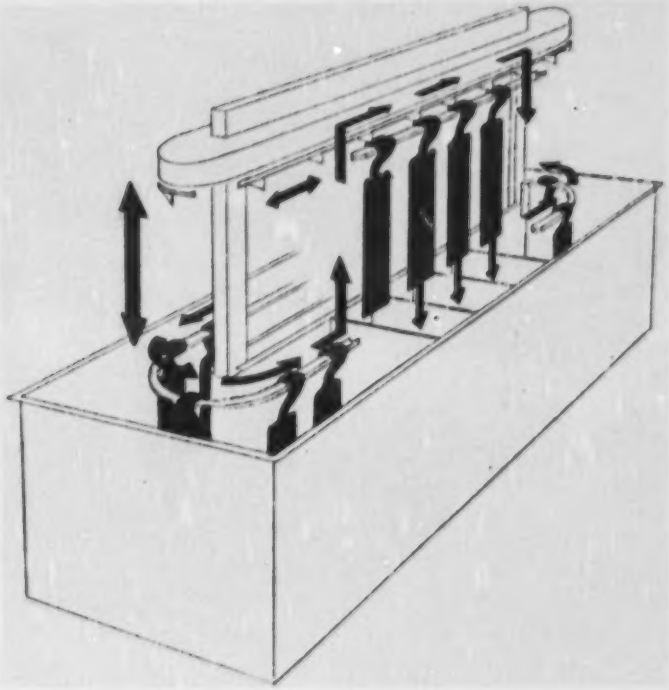


Figure I-1. Return-type automatic system: medium duty rack application.

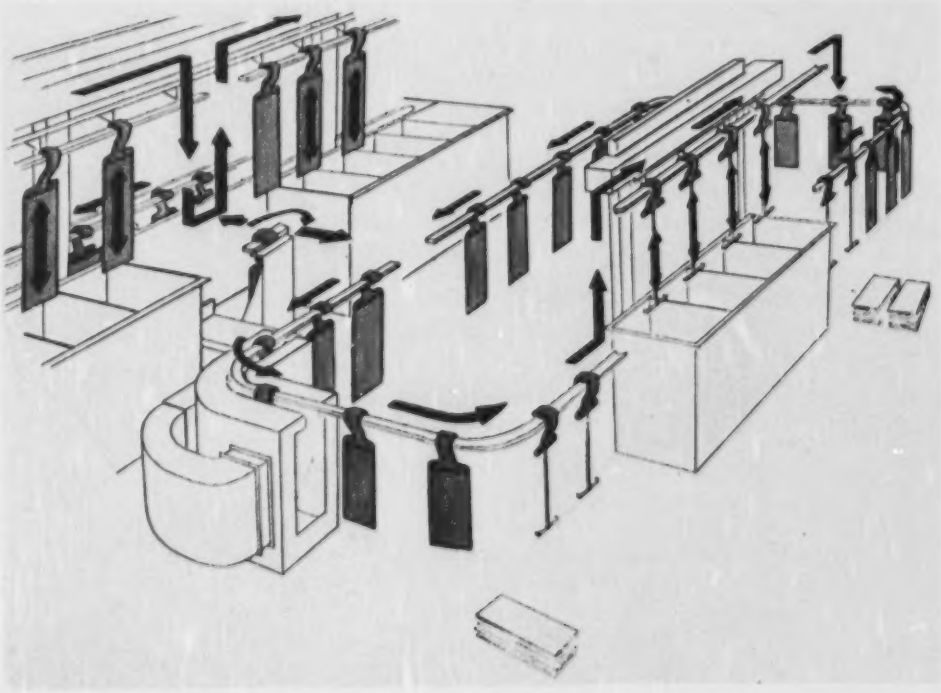


Figure I-2. Conveyorized automatic loading and unloading.

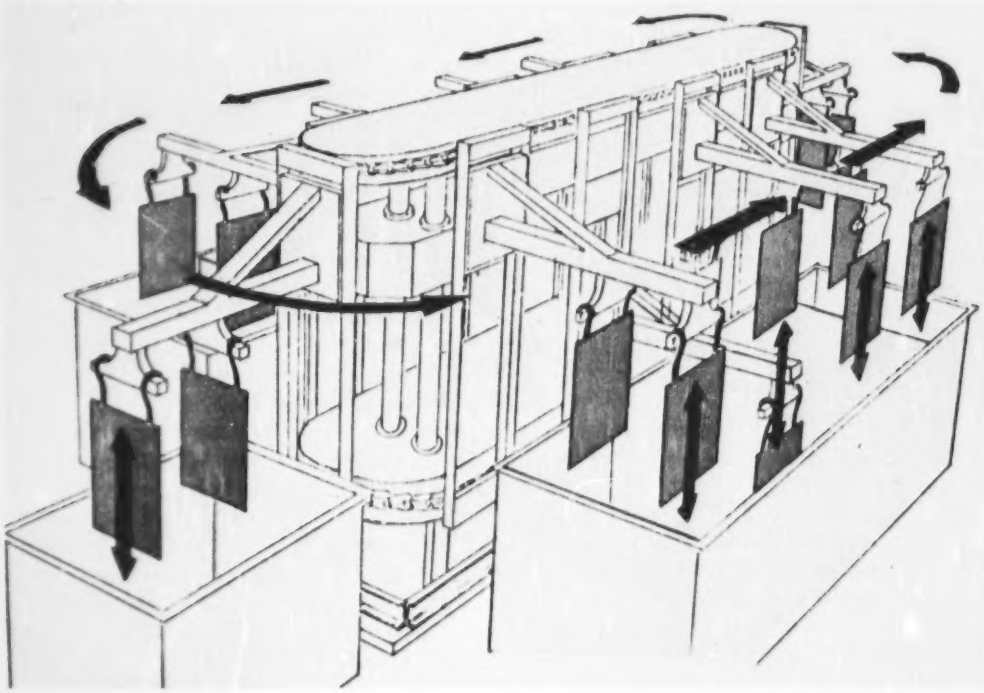


Figure I-3. Sidearm return-type automatic systems: heavy duty applications.

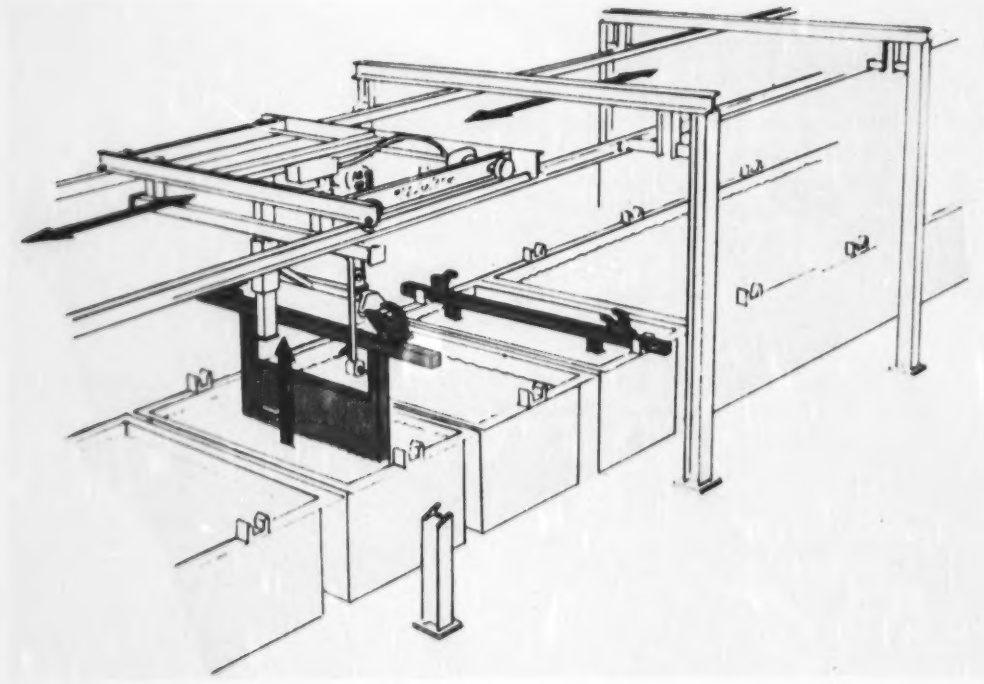


Figure I-4. Programed automatic hoist system: heavy duty applications.

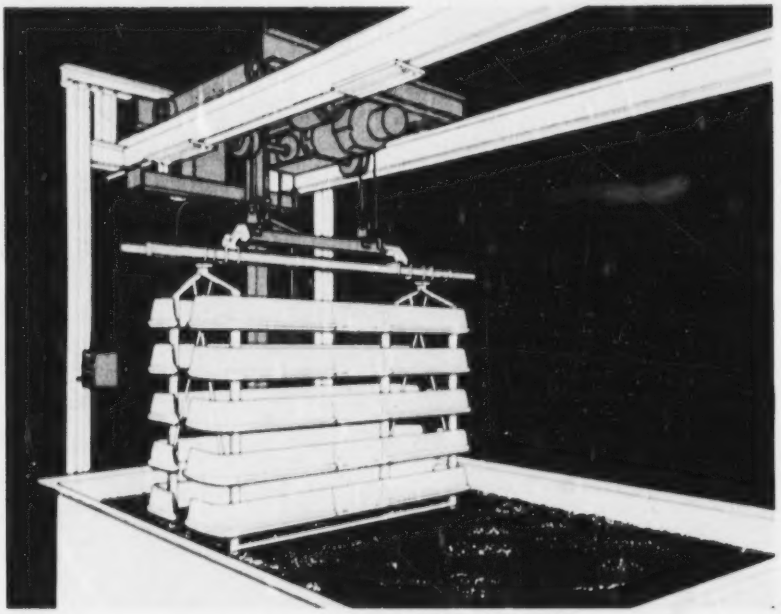


Figure I-5. Typical heavy duty application.

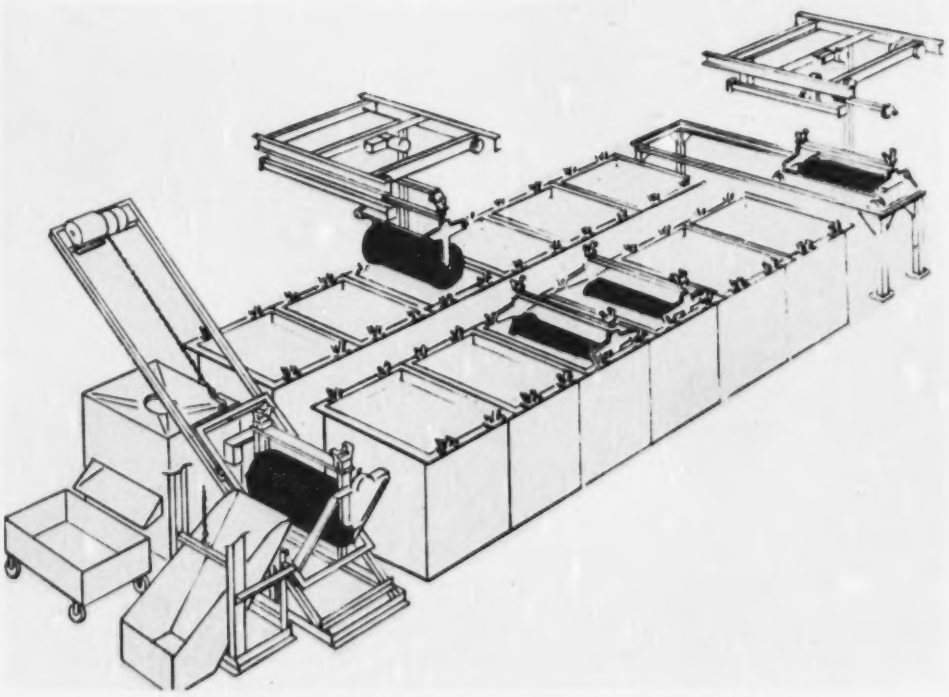


Figure I-6. Programed hoist system: bulk-finishing applications.

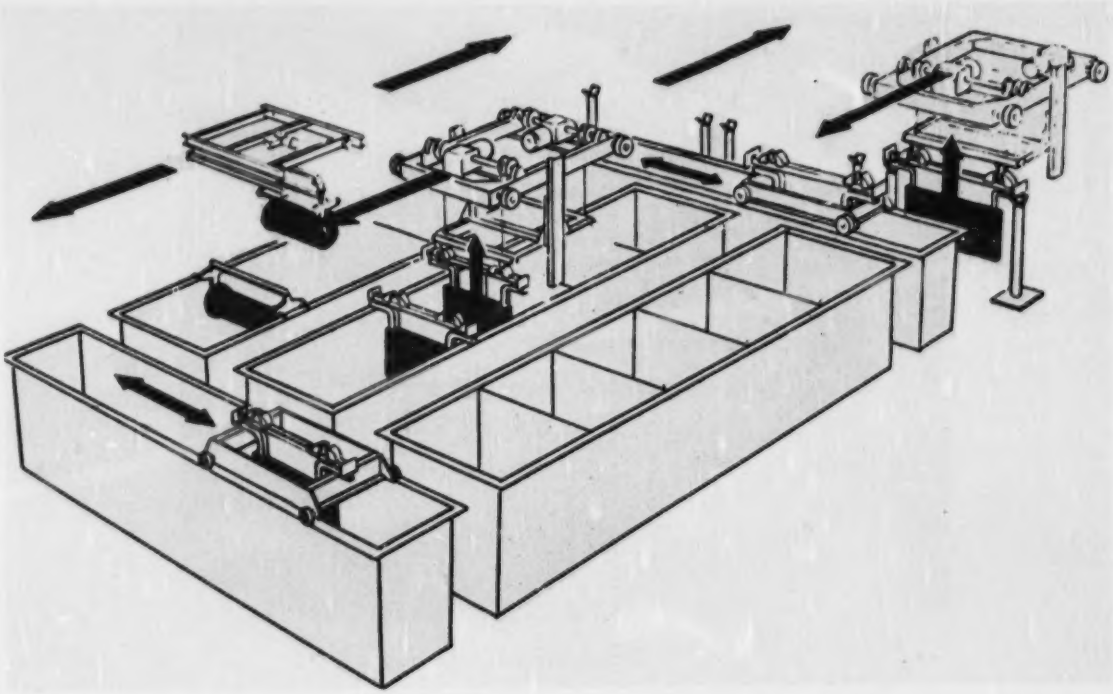


Figure I-7. Programed automatic hoist system: bulk-finishing applications.

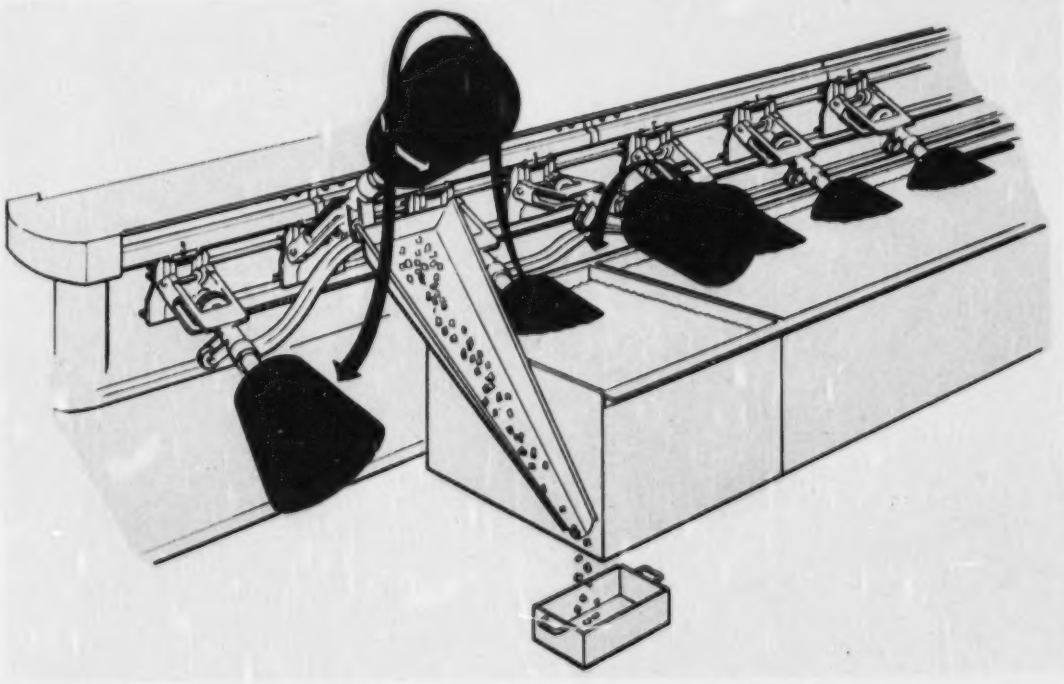


Figure I-8. Oblique-barrel automatic system: bulk-finishing applications.

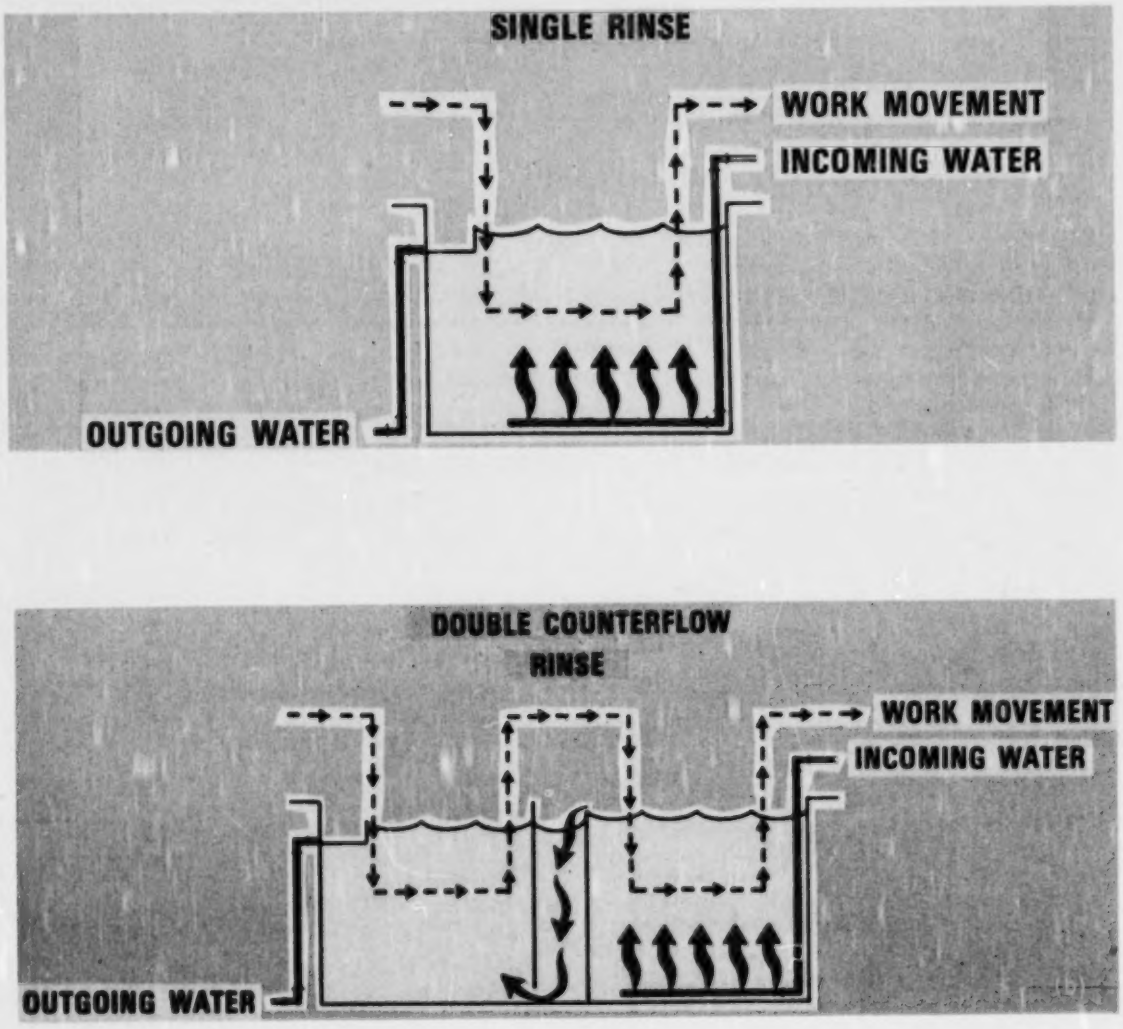


Figure I-9. Counterflow multiple-tank rinsing: (a) single rinse; (b) double counterflow rinse.

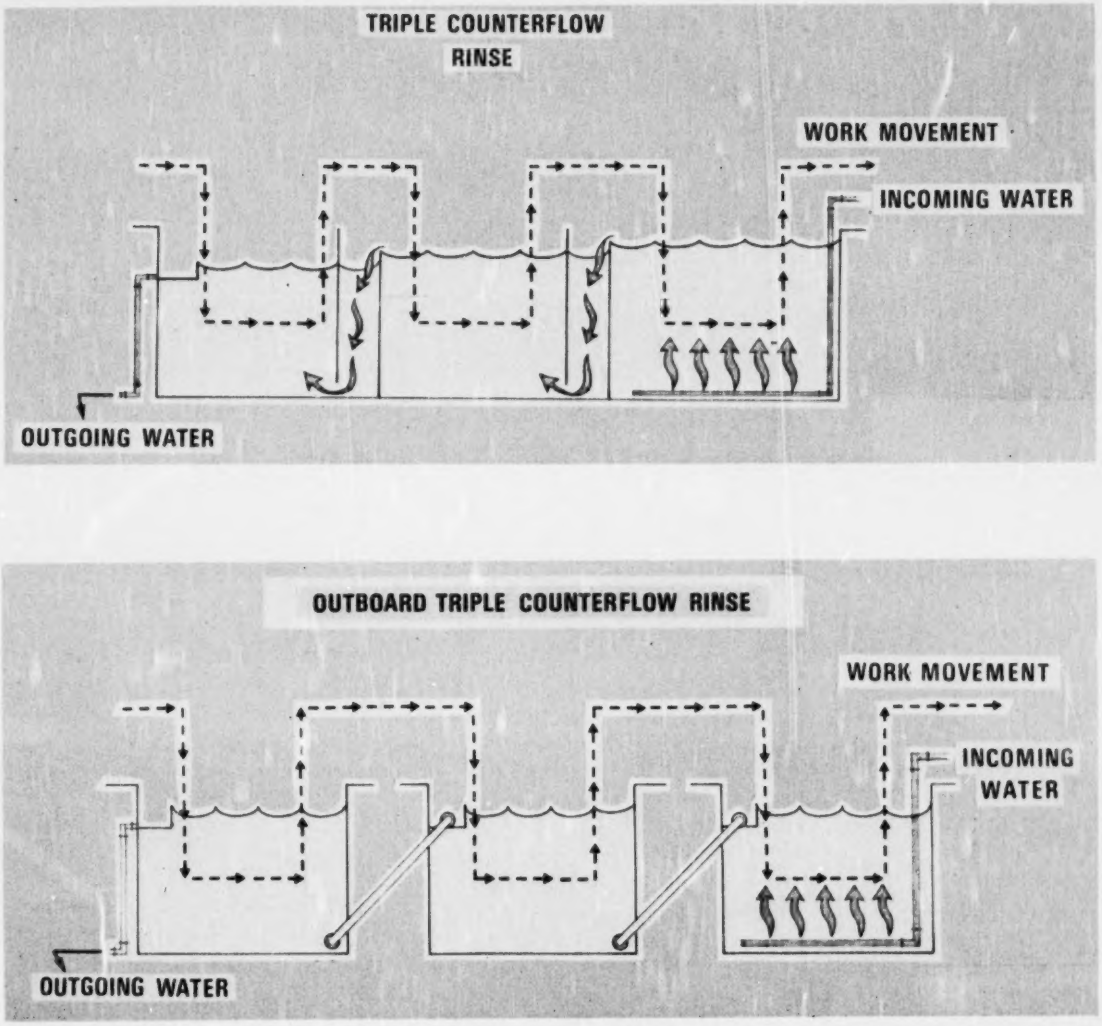


Figure I-10. Counterflow multiple-tank rinsing: (a) triple counterflow rinse; (b) outboard triple counterflow rinse.

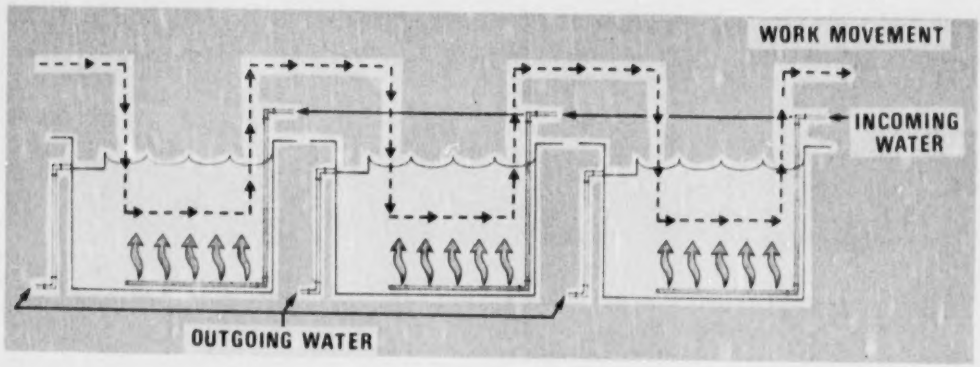


Figure I-11. Multiple-tank rinsing.

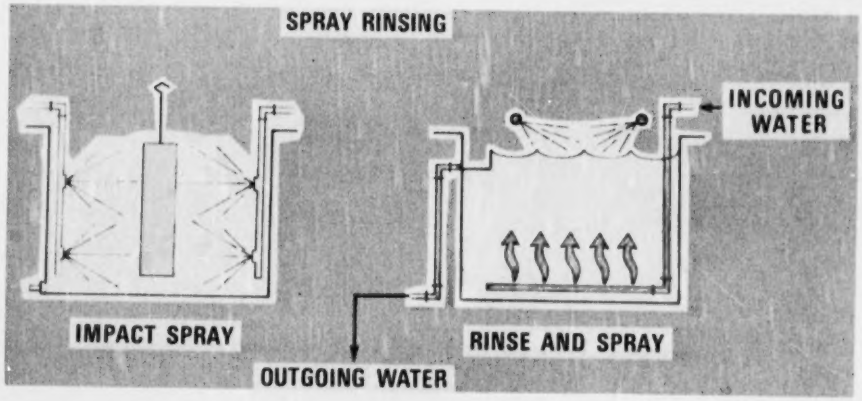


Figure I-12. Spray rinsing.

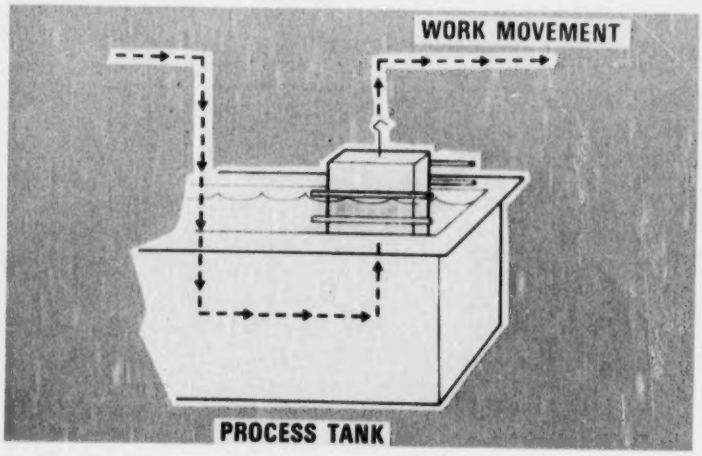


Figure I-13. Fog rinsing.

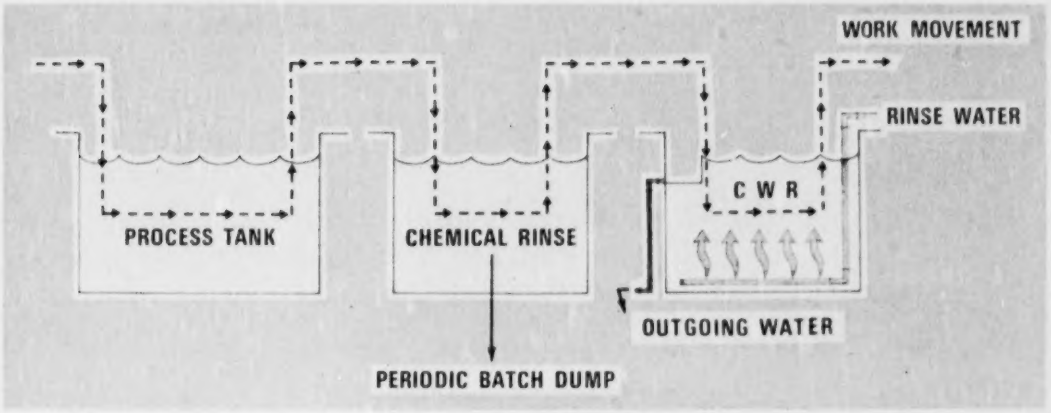


Figure I-14. Chemical rinsing.

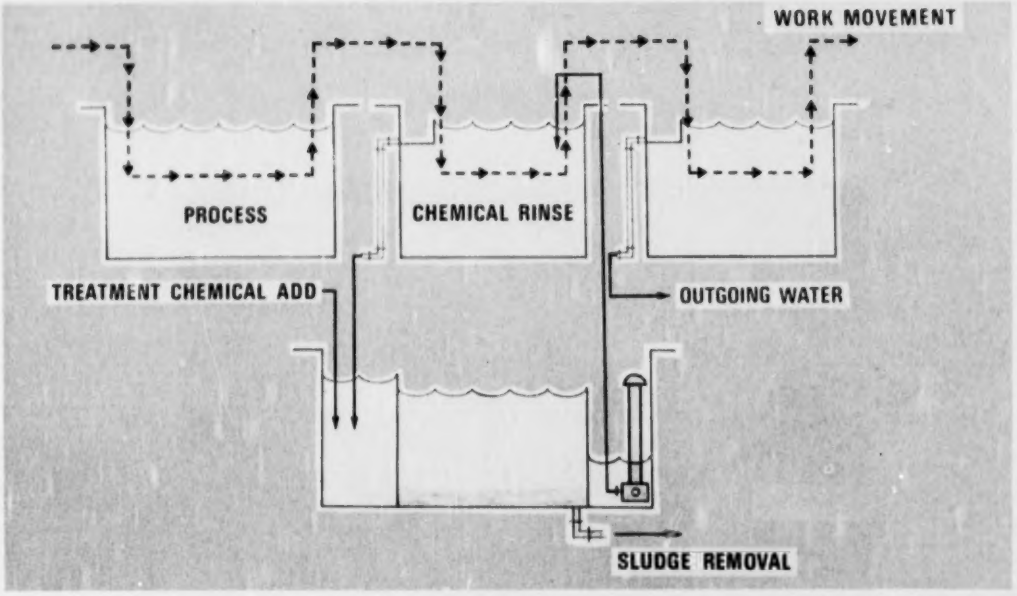


Figure I-15. Integrated chemical rinse.

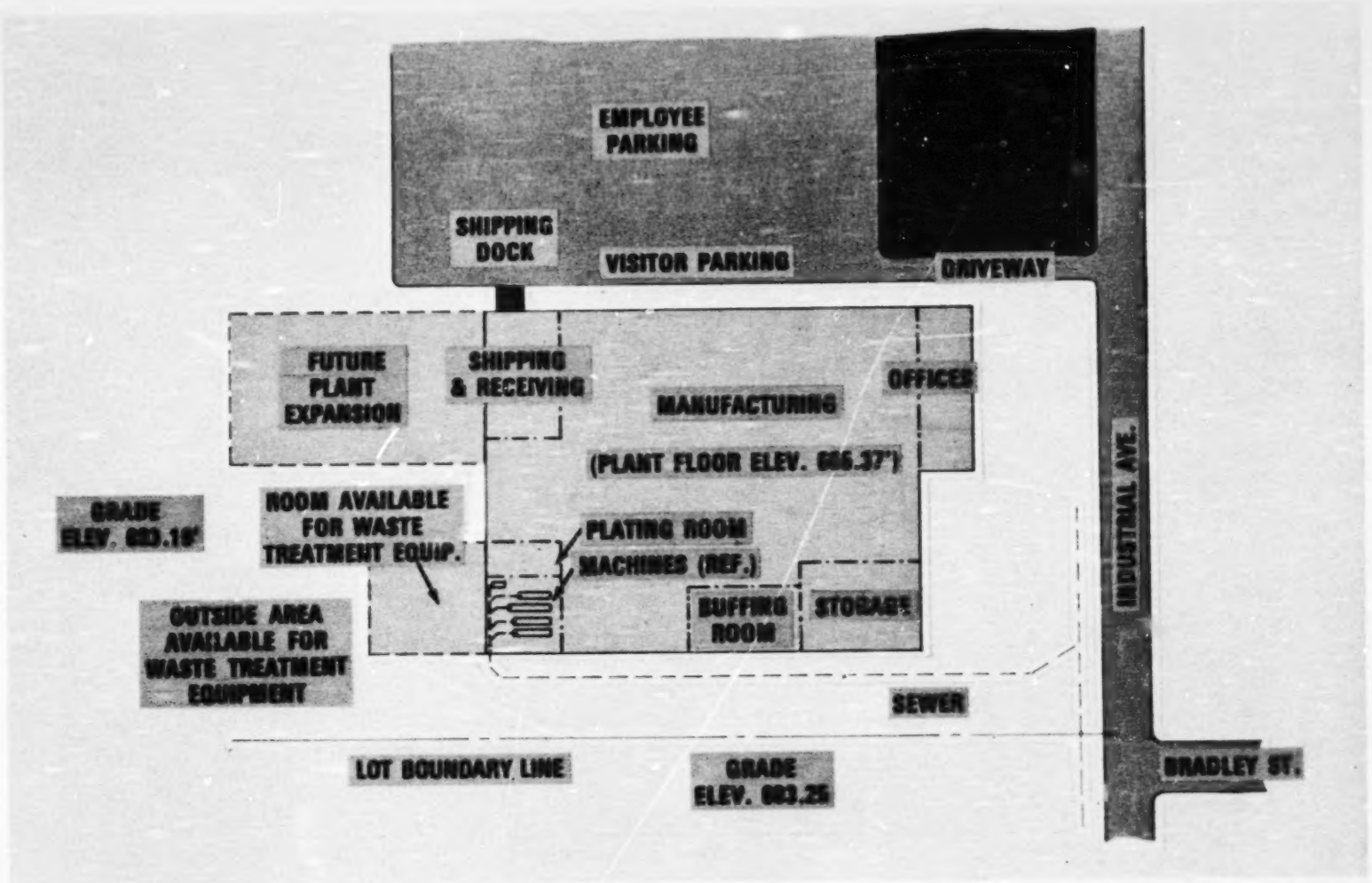


Figure I-16. Company X site plan.

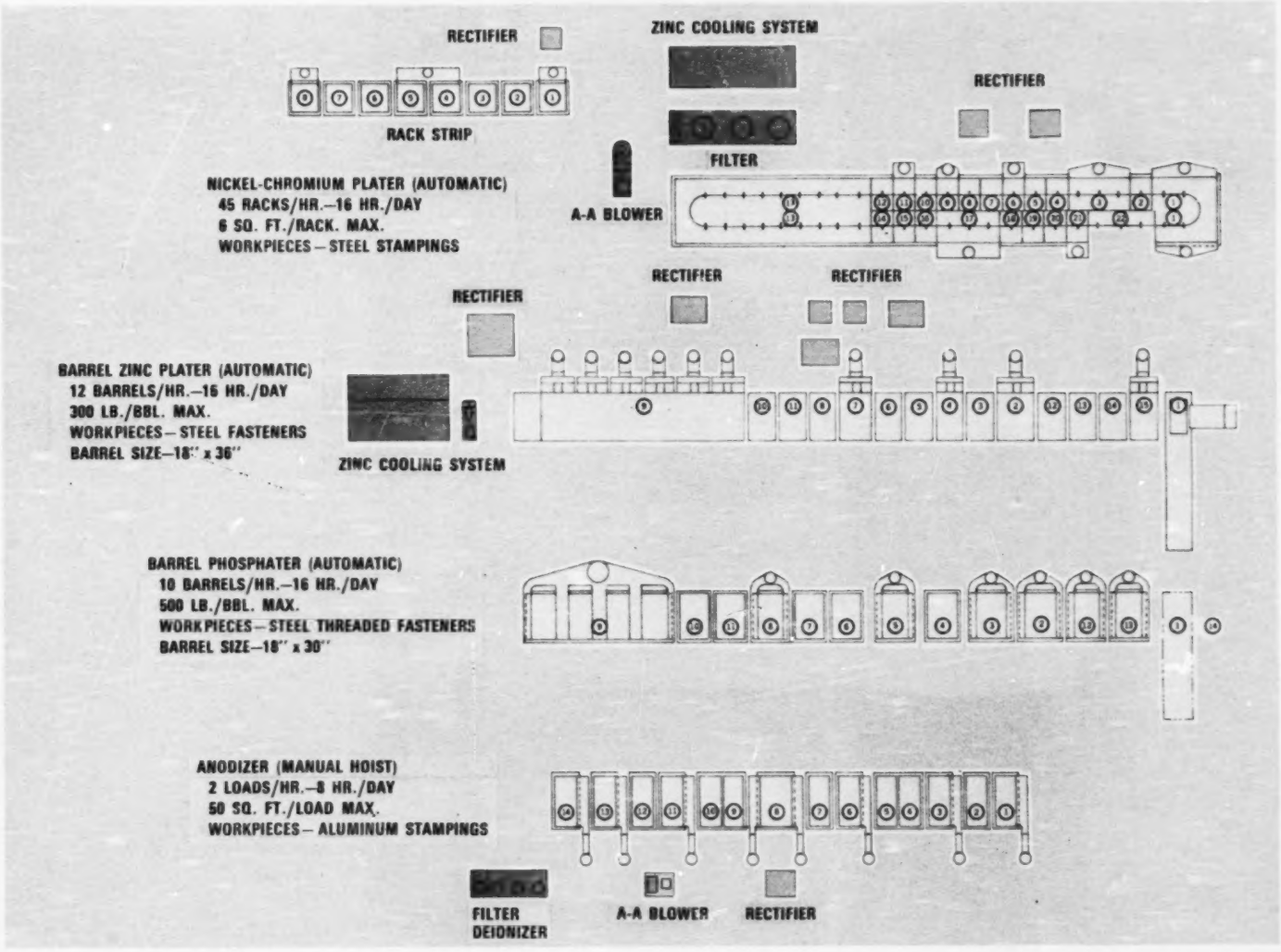


Figure I-17. Company X equipment layout.

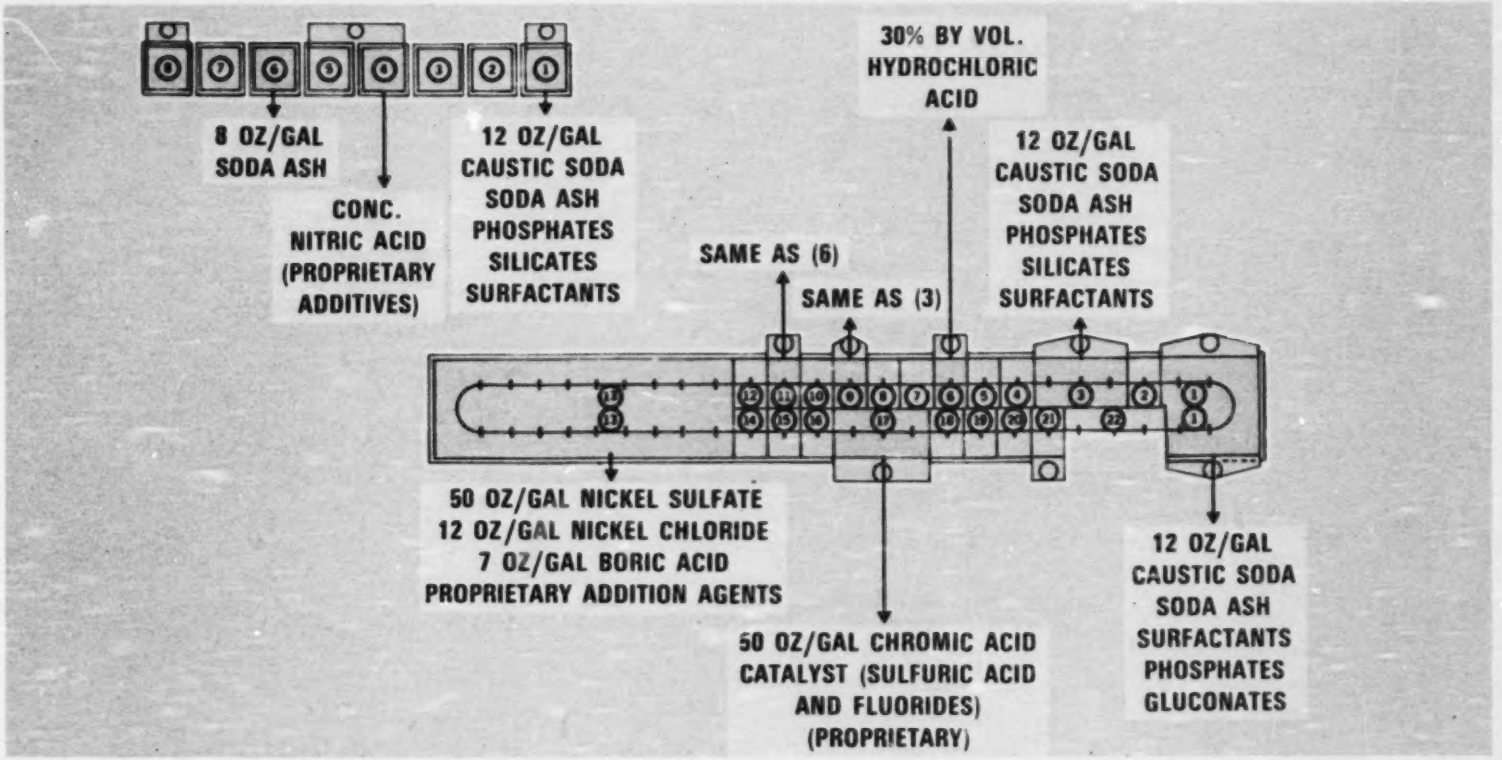
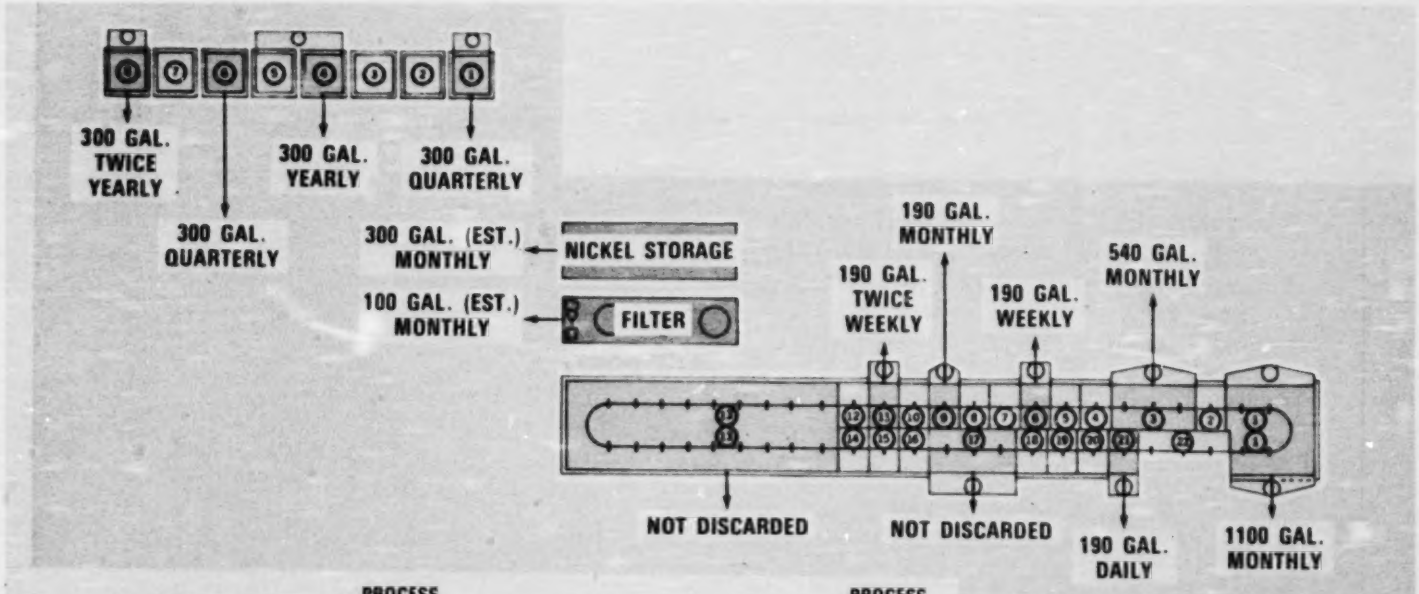


Figure I-18. Nickel-chromium plater process composition.



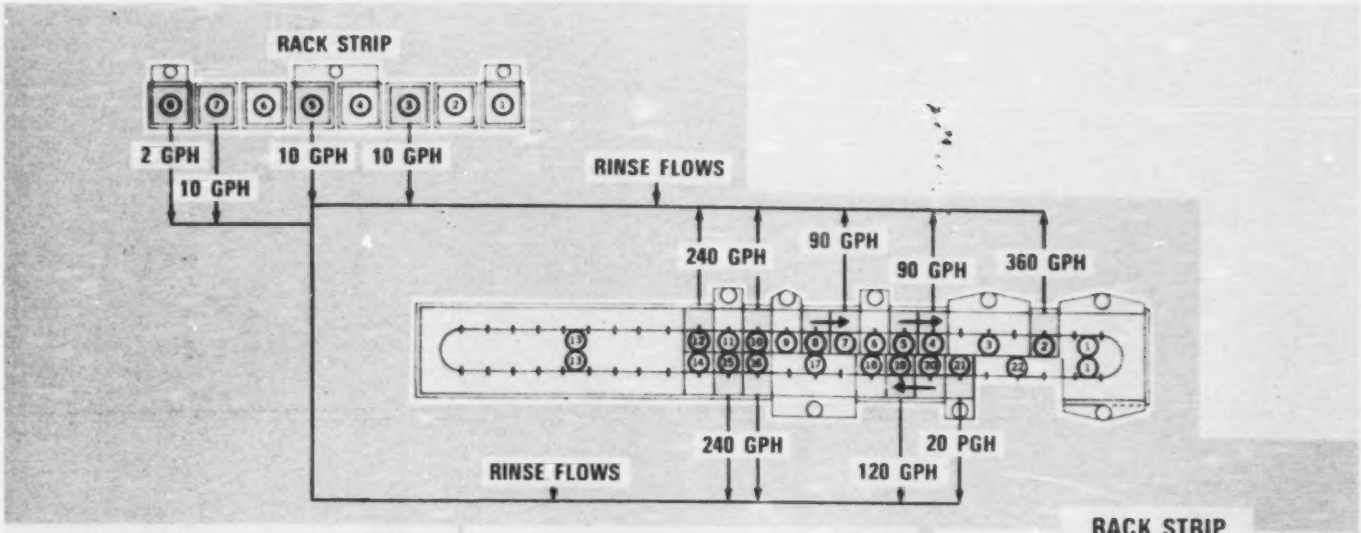
PROCESS	PROCESS TANK CAPACITY
1. SOAK CLEAN	1100 GAL.
2. C.W. RINSE	
3. ANODIC CLEAN	540 GAL.
4. C.W. RINSE	
5. C.W. RINSE & SPRAY	
6. ACID	190 GAL.
7. C.W. RINSE	
8. C.W. RINSE & SPRAY	
9. ANODIC CLEAN	190 GAL.
10. C.W. RINSE & SPRAY	
11. ACID	190 GAL.

PROCESS	PROCESS TANK CAPACITY
12. C.W. RINSE	
13. NICKEL PLATE	3300 GAL.
14. DRAGOUT	
15. C.W. RINSE	
16. C.W. RINSE	
17. CHROME PLATE	560 GAL.
18. DRAGOUT	
19. C.W. RINSE	
20. C.W. RINSE & SPRAY	
21. H.W. RINSE	190 GAL.
22. LOAD & UNLOAD	

RACK STRIP

PROCESS	RINSE TANK CAPACITY
1. CHROME STRIP	300 GAL.
2. DRAIN	
3. C.W. RINSE	
4. NICKEL STRIP	300 GAL.
5. C.W. RINSE	
6. NEUTRALIZE	300 GAL.
7. C.W. RINSE	
8. H.W. RINSE	300 GAL.

Figure I-19. Nickel-chromium plater and rack strip dumping schedule: spent processes.



PROCESS	RINSE TANK CAPACITY
1. SOAK CLEAN	
2. C.W. RINSE	190 GAL.
3. ANODIC CLEAN	
4. C.W. RINSE COUNTERFLOW	190 GAL.
5. C.W. RINSE & SPRAY	190 GAL.
6. ACID	
7. C.W. RINSE	190 GAL.
8. C.W. RINSE COUNTERFLOW & SPRAY	190 GAL.
9. ANODIC CLEAN	
10. C.W. RINSE & SPRAY	190 GAL.
11. ACID	

PROCESS	RINSE TANK CAPACITY
12. C.W. RINSE	190 GAL.
13. NICKEL PLATE	
14. DRAGOUT	
15. C.W. RINSE	190 GAL.
16. C.W. RINSE	190 GAL.
17. CHROME PLATE	
18. DRAGOUT	
19. C.W. RINSE COUNTERFLOW	190 GAL.
20. C.W. RINSE & SPRAY	190 GAL.
21. H.W. RINSE	190 GAL.
22. LOAD & UNLOAD	

RACK STRIP

PROCESS	RINSE TANK CAPACITY
1. CHROME STRIP	
2. DRAIN	
3. C.W. RINSE	300 GAL.
4. NICKEL STRIP	
5. C.W. RINSE	300 GAL.
6. NEUTRALIZE	
7. C.W. RINSE	300 GAL.
8. H.W. RINSE	300 GAL.

Figure I-20. Nickel-chromium plater and rack-strip rinse-water data.

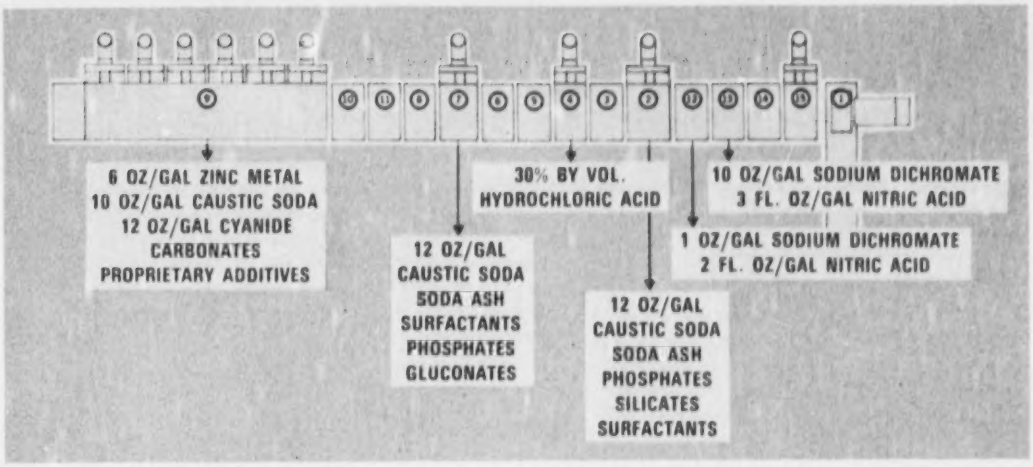
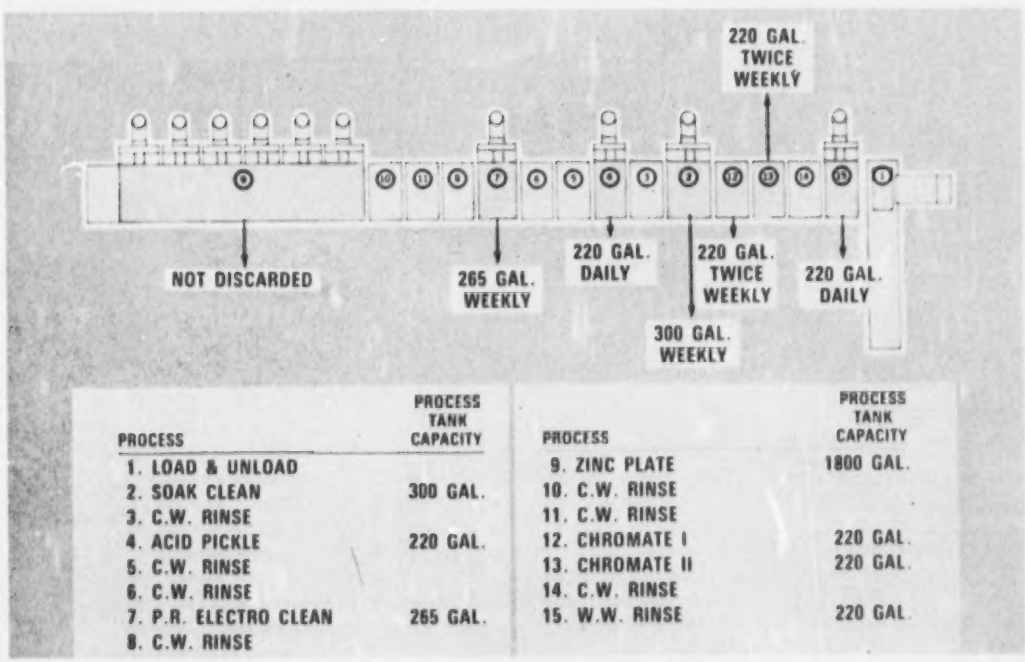


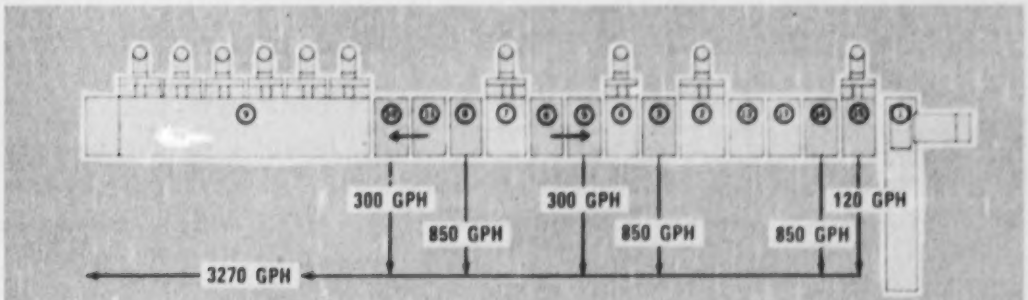
Figure I-21. Zinc plater process composition.



PROCESS	PROCESS TANK CAPACITY
1. LOAD & UNLOAD	
2. SOAK CLEAN	300 GAL.
3. C.W. RINSE	
4. ACID PICKLE	220 GAL.
5. C.W. RINSE	
6. C.W. RINSE	
7. P.R. ELECTRO CLEAN	265 GAL.
8. C.W. RINSE	

PROCESS	PROCESS TANK CAPACITY
9. ZINC PLATE	1800 GAL.
10. C.W. RINSE	
11. C.W. RINSE	
12. CHROMATE I	220 GAL.
13. CHROMATE II	220 GAL.
14. C.W. RINSE	
15. W.W. RINSE	220 GAL.

Figure I-22. Barrel zinc plater dumping schedule: spent process.



PROCESS	RINSE TANK CAPACITY	PROCESS	RINSE TANK CAPACITY
1. LOAD & UNLOAD		9. ZINC PLATE	
2. SOAK CLEAN		10. C.W. RINSE COUNTERFLOW	220 GAL.
3. C.W. RINSE	220 GAL.	11. C.W. RINSE	220 GAL.
4. ACID PICKLE		12. CHROMATE I	
5. C.W. RINSE COUNTERFLOW	220 GAL.	13. CHROMATE II	
6. C.W. RINSE	220 GAL.	14. C.W. RINSE	220 GAL.
7. P.R. ELECTRO CLEAN		15. W.W. RINSE	220 GAL.
8. C.W. RINSE	220 GAL.		

Figure I-23. Barrel zinc plater rinse-water data.

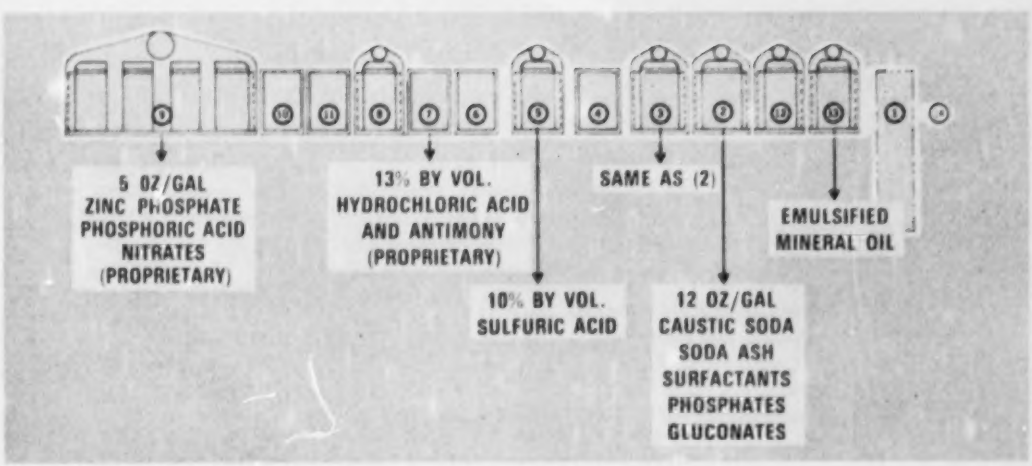
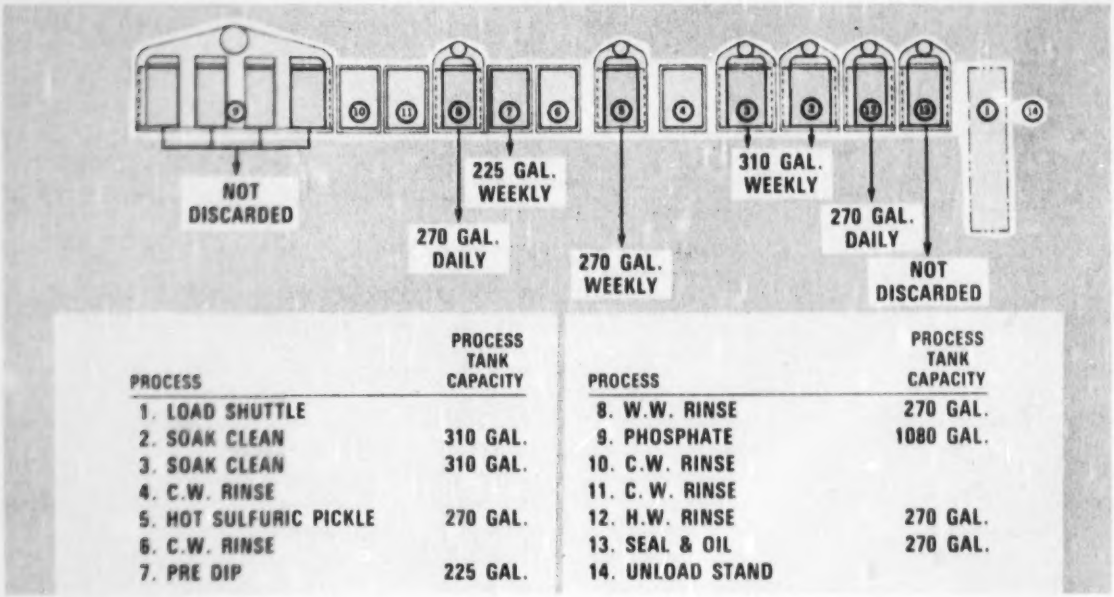


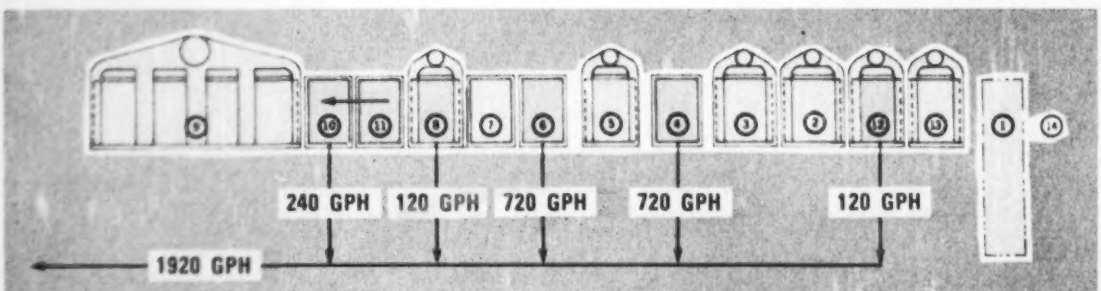
Figure I-24. Phosphater process composition.



PROCESS	PROCESS TANK CAPACITY
1. LOAD SHUTTLE	
2. SOAK CLEAN	310 GAL.
3. SOAK CLEAN	310 GAL.
4. C.W. RINSE	
5. HOT SULFURIC PICKLE	270 GAL.
6. C.W. RINSE	
7. PRE DIP	225 GAL.

PROCESS	PROCESS TANK CAPACITY
8. W.W. RINSE	270 GAL.
9. PHOSPHATE	1080 GAL.
10. C.W. RINSE	
11. C. W. RINSE	
12. H.W. RINSE	270 GAL.
13. SEAL & OIL	270 GAL.
14. UNLOAD STAND	

Figure I-25. Phosphate dumping schedule: spent process.



PROCESS	RINSE TANK CAPACITY
1. LOAD SHUTTLE	
2. SOAK CLEAN	
3. SOAK CLEAN	
4. C.W. RINSE	225 GAL.
5. HOT SULFURIC PICKLE	
6. C.W. RINSE	225 GAL.
7. PRE DIP	

PROCESS	RINSE TANK CAPACITY
8. W.W. RINSE	270 GAL.
9. PHOSPHATE	225 GAL.
10. C.W. RINSE ┐COUNTERFLOW	225 GAL.
11. C.W. RINSE ┘	225 GAL.
12. H.W. RINSE	270 GAL.
13. SEAL & OIL	
14. UNLOAD STAND	

Figure I-26. Barrel phosphater rinse-water data.

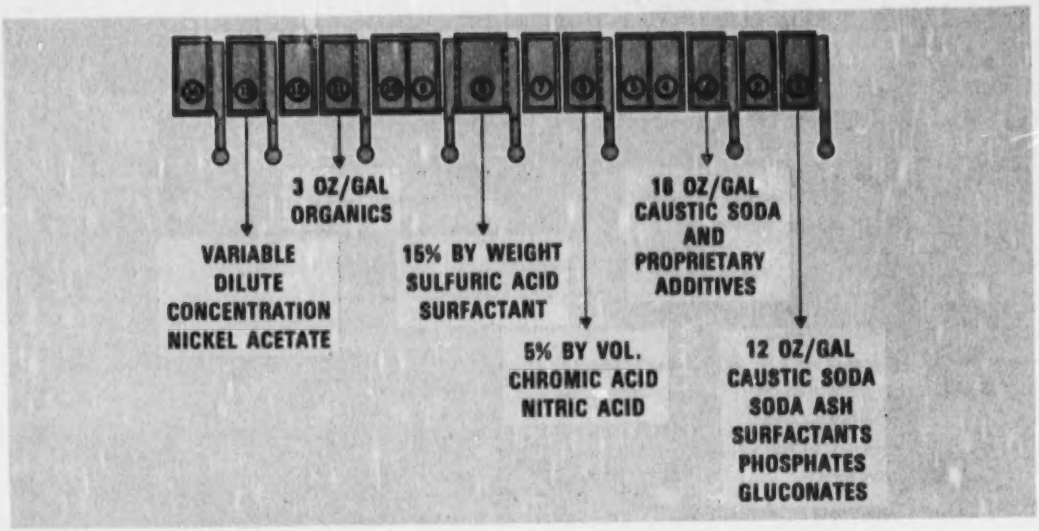
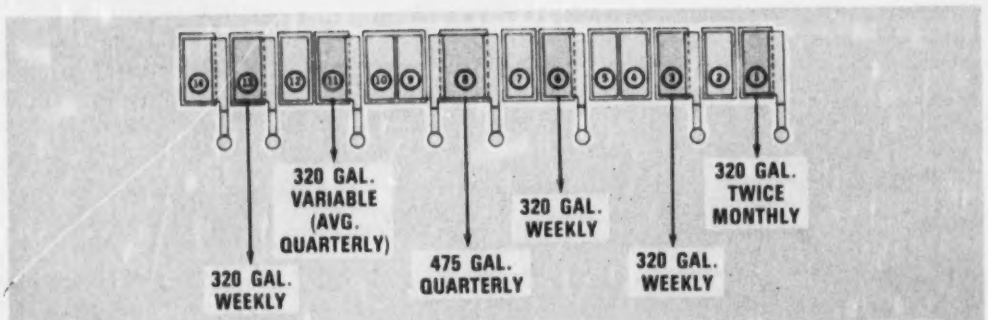


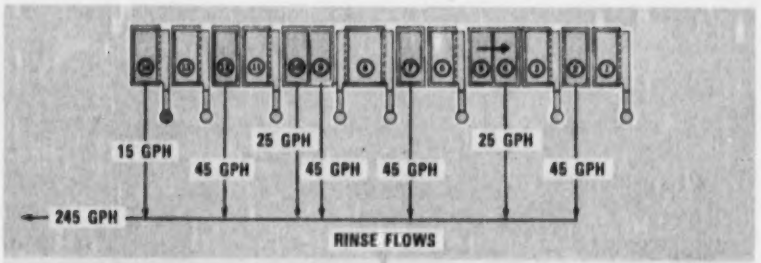
Figure I-27. Anodizer process composition.



PROCESS	PROCESS TANK CAPACITY
1. SOAK CLEAN	320 GAL.
2. RINSE	
3. CAUSTIC ETCH	320 GAL.
4. RINSE	
5. RINSE	
6. DESMUT	320 GAL.
7. RINSE	

PROCESS	PROCESS TANK CAPACITY
8. ANODIZE	475 GAL.
9. RINSE	
10. D.I. RINSE	
11. DYE	320 GAL.
12. RINSE	
13. HOT WATER SEAL	320 GAL.
14. WARM D.I. RINSE	

Figure I-28. Anodizer dumping schedule: spent processes.



PROCESS	RINSE TANK CAPACITY	PROCESS	RINSE TANK CAPACITY
1. SOAK CLEAN		8. ANODIZE	
2. RINSE	320 GAL.	9. RINSE	320 GAL.
3. CAUSTIC ETCH		10. D.I. RINSE	320 GAL.
4. RINSE COUNTERFLOW	320 GAL.	11. DYE	
5. RINSE	320 GAL.	12. RINSE	320 GAL.
6. DESMUT		13. HOT WATER SEAL	
7. RINSE	320 GAL.	14. WARM D.I. RINSE	320 GAL.

Figure I-29. Anodizer rinse-water data.

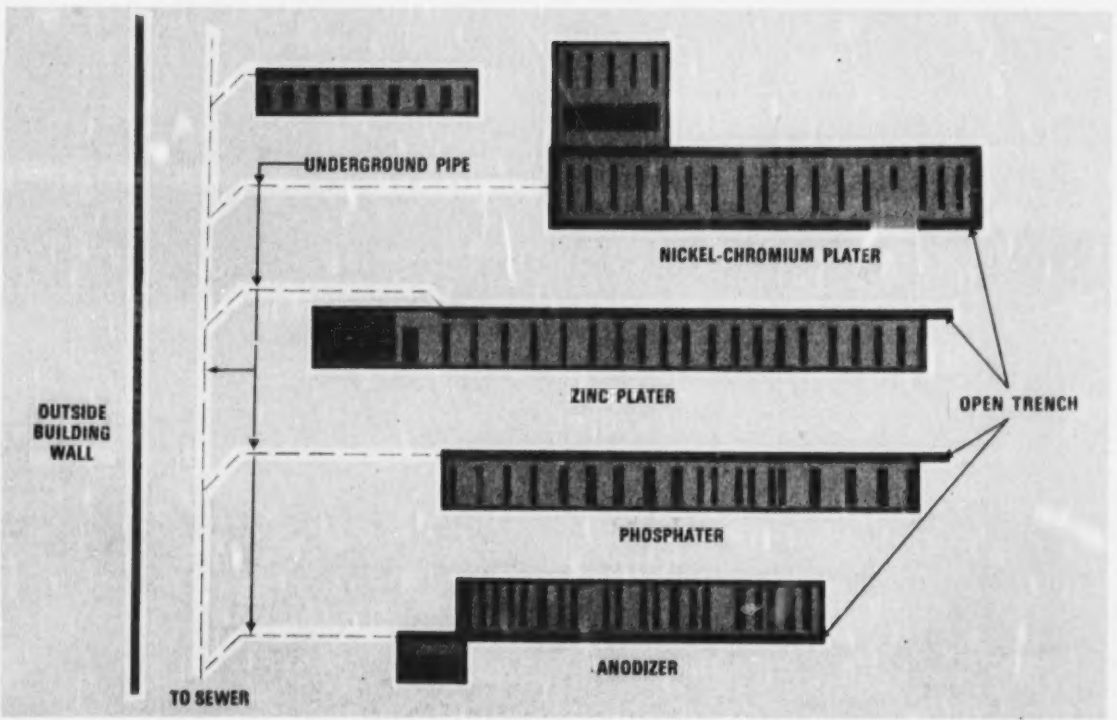


Figure I-30. Foundation layout.

Chapter II

VENTILATION AND AIR-POLLUTION CONTROL

INTRODUCTION

In the discussion of any ventilation system for a metal-finishing operation, two distinct areas should be covered. These areas are

- The ventilation of the fumes from the work area
- The removal of any contaminants from the exhaust stream that can cause an air-pollution hazard

In addition to a general discussion of these points, this part of the paper will also deal with some of the operating and design principles upon which ventilation and air-pollution-control equipment is based. It is mandatory that the owner and operator of the metal-finishing equipment have a general idea of the principles involved so that he can make the best selection of design and equipment for his own application. In the final analysis, the owner is the one responsible for the proper operation and function of the equipment.

Even if he has recourse back to the supplier, the owner should never assume that a vendor's "guarantee" absolves him of all responsibility. The owner also should consider carefully all vendors to assure that, if legal recourse is required, the vendor is economically strong enough to back up his guarantee.

The owner should also be able to understand the operating and design principles behind the vendor's equipment well enough so that he has a high degree of technical confidence in the vendor's guarantee. It is ludicrous for the owner not to be able to judge the technical merits of the design and operation of any vendor's equipment when he is the one responsible to the pollution-control authorities for the proper operation of his plant and equipment. For this reason alone, the owner should be competent to analyze and compare the vendor's equipment and quotation beyond the simple "first cost price comparison." When the control authorities want to padlock the door for creating an air-pollution hazard, they will not be impressed by how much money the owner saved by purchasing the least expensive equipment.

To prevent action by any air-pollution authority, the owner must be confident that the equipment he selects will perform satisfactorily for many years, will satisfy the existing air-pollution requirements, and will meet all other codes and regulatory requirements, including the Occupational Safety and Health Act (OSHA).

VENTILATION

OSHA Considerations

OSHA[1] has specific guidelines for the design and evaluation of exhaust systems.

The primary requisite for any ventilation system as required by the OSHA is to assure that any airborne toxic material be held below the threshold limit value (TLV) or the maximum allowable concentration (MAC). Both the TLV and MAC mean essentially the same thing in that it has been experienced that this concentration of toxic materials will not affect materially the health of any worker so exposed for a period of 8 hours per working day for his entire working life. The values of the TLV are those determined by various governmental agencies; the OSHA does include a listing of these as published by the American Conference of Governmental Industrial Hygienists.[2]

In addition to the requirement that all ventilation systems "be adequate to reduce the concentration of the air contaminant to the degree that a hazard to the worker does not exist," OSHA[1] also lists a specific method for determining exhaust rates from each tank. This determination is as published by the Committee on Industrial Ventilation's "Industrial Ventilation" handbook,[2] 12th edition. It should be noted here that in most cases the ventilation rates recommended in this 12th edition are higher than those listed for identical applications in previous editions. OSHA in effect states that in many cases additional exhaust volumes are needed to control the contaminant at less than the TLV in the area immediately surrounding the tanks being exhausted.

In the past, lower rates have accomplished this control in most applications. Care must be exercised, however, in the initial design to provide an area where crossdrafts are a minimum. To do this, the location of windows and doors becomes extremely critical and should be watched carefully in the vicinity where exhaust of the metal-finishing tanks is required. Other considerations—such as traffic patterns, workflow, method of work movement, and location of personnel—must be studied.

When planning a new system or revising an existing system, special emphasis should be placed on how workers are exposed to possible contaminants. Obviously, the farther away you can keep your workers and the greater the internal dilution, the lower exhaust rate required to keep contaminants below the TLV level. Fresh air movement into the area should be controlled such that it flows past the worker at his work station.

These, then, are the considerations that should be taken into account in order to comply with OSHA.

Other Factors

In addition to the foregoing considerations, there should be other factors that will help in the overall design of the exhaust system designed and installed.

One of the most critical items in any ventilation system is the proper amount of makeup air that is provided. The amount of makeup air should be slightly less than the total volume being exhausted, but the amount of this difference should be less than 2-5 percent. Many ventilation manuals state that the amount of makeup air should be greater than the amount of exhaust air. When dealing with toxic contaminants and air-pollution-control requirements, however, it is mandatory to keep control of the toxic fumes in the area where they can be removed effectively.

Having a positive pressure within this area means that wherever windows are open or doors are open, airflow will be out of the immediate area, and consequently toxic contaminants can find their way into other areas of the building. In any building, it is suggested that the metal-finishing operation where tanks are involved be segregated somewhat from the remainder of the area. In this fashion, makeup air can be supplied to the remaining portion of the building at an excess quantity, with sufficient air makeup to cover the slight negative values that would be found in the metal-finishing tank area. This method, then, will insure that all airborne contaminants would be carried through the ventilation system in the metal-finishing area, which has been specifically designed and constructed to handle these contaminants.

Materials of Construction

Obviously, the ventilation system in the metal-finishing area should be constructed of corrosion-resistant materials that are also fire retardant. Some of the considerations that should be given to materials of construction would be the following:

- Corrosion resistance to contaminants being handled
- Physical strength of the materials
- Fire retardance
- First cost and installation cost
- Ease of modification

Over the past 15 years, it has been proven that solid plastic construction materials used in ventilation systems offer many of these advantages at low first cost, and they are installed readily by most personnel. Solid plastic materials available include polyvinyl chloride (PVC), polyethylene, polypropylene, glass-reinforced polyester, as well as other glass-reinforced thermosetting materials.

The first three materials listed are thermoplastics, which are by their very nature susceptible to heat degradation at high temperatures but are effective when it is expected that operating temperatures within the system are kept well below the upper operating limits generally recommended. These operating limits are as follows:

PVC, 140° F

Polyethylene, 200° F

Polypropylene, 230° F

Thermosetting resins, such as glass-reinforced polyesters, do not exhibit the same physical strength loss with increase in temperature and do expand at a slightly lower rate than most of the thermoplastics. Glass-reinforced polyesters used in ventilation systems have operated successfully at temperatures in excess of 250° F. They can be made fire retardant, and will contain fire and smoke should a fire occur.

Although PVC generally is regarded as noncombustible, it does give off copious quantities of HCl when burned, and will drop flaming globules when exposed to a fire. In several cases, PVC fires have snuffed themselves out in a relatively short period of time, but extensive structural steel damage has been caused by the large amount of HCl generated. In other cases, it has been shown that PVC has spread the fire by dripping these flaming globules of molten PVC plastic. Polyethylene

is combustible and generally is not recommended where fire retardance is a prime requisite—which should always be the case in a metal-finishing operation. Polypropylene is available in fire-retardant grades, but this material will burn at a faster rate than a comparable glass-reinforced polyester.

The key to the effective design of any ventilation system is to follow some specific guidelines. The "Industrial Ventilation" manual[2] offers excellent advice about the basic components of the ventilation system.

In addition to this information, it is recommended generally that duct velocities in the range of 2,500-3,500 ft/min be used for ventilation systems for metal-finishing operations. This range generally keeps the static pressure in the total duct system to a reasonable amount, generally in the range of 1.5-3 inches water gage.

Hoods

Exhaust hoods should be designed to insure the capture of all fumes generated from the tanks. It is important to remember that the maximum fuming occurs when the work is placed in the tank and as the work is removed from the tank. It is mandatory, therefore, that the pickup points be arranged to capture the fumes in these areas. If the tank is hot the fumes tend to rise; therefore, pickup points should be installed above the point where the maximum height of work occurs during this transferring operation.

In addition to consideration for the pickup points, additional consideration should be given to providing baffles of some type around the immediate hood itself. The addition of 12 inches or more of baffles beyond all extremities of the hood can increase materially the effectiveness of the removal of the contaminants from the tank area. It is surprising how much more effective a hood can be when it is baffled and when the pickup points are located properly.

In general, for most metal-finishing operations, slot hoods are used, as these tend to give equal distribution to the suction of the fumes across the width of the tank. Slot velocities in the slot hoods are kept generally in the range of 2,000-3,000 ft/min, due to the high static pressure created with this type of arrangement. A slot hood with this velocity generally will have no more than ½-¾ inch static pressure for the hood itself.

The design of the hood in the duct system should be based on the following premises:

Containment of the Fumes. The fumes should be kept in the tank area until they can be picked up thoroughly by the exhaust hood. Additional baffles or artificial walls will assist in this operation. Baffles tend to eliminate the crossdrafts and also help to contain the fumes in the tank area. It is sometimes evident that baffles are also required directly above the maximum height of work to control the fumes from rising too rapidly before they are picked up into the exhaust hood.

Controlled Airflow Into the Fuming Area. The placement of the tanks within the room and the location of items that can contribute to crossdrafts should be studied carefully. The objective is to maintain the flow of air into the tank area in such a fashion that it constantly flows past the work stations and toward the exhaust hoods. A study on paper of the location of windows and doors, as well as of the location of the tanks themselves in relationship to these openings, is important. Consideration for baffles and rearrangement of tanks within a given area can sometimes eliminate problems and reduce the total amount of ventilation required to keep the contaminants below the TLV in the work area. Baffles extended on either side of the tanks, as well as between all hoods, as mentioned earlier, help the orderly flow of air into this area and generally assist the exhaust system in performing its vital function, that is to say, removal of the contaminants.

Removal of the Fumes From the Tank Area. Although it may seem redundant, it is important that this third item be included with the first two because the amount of exhaust air used for a given tank or tanks must be adequate to remove the fumes from the area in which they are being contained as quickly as possible. Obviously, an inadequate amount of exhaust air allows the fumes to linger in the exhaust area for too long a period of time, permitting their eventual escape into the room itself with possible contamination of the entire working area. In general, the exhaust volume should be 100-200 cfm for heated tanks and not less than 50-75 cfm for cool tanks. However, the "Industrial Ventilation" manual[2] or OSHA[1] should be studied before any exhaust volumes are defined in a given situation. The values given here can be used only if the fumes are contained and the airflow into the area is controlled as indicated above.

Ductwork

In addition to the design and location of the hoods and other items, some consideration should be given to the runs of ductwork themselves. The duct runs should be sloped and drainage points provided so that condensation on the interior of the duct walls can be controlled. The duct construction material should be such that if a leak occurs due to physical damage, repairs can be effected easily to eliminate this potential source of pollution into a sewer system not equipped to handle toxic contaminants. In general, the design of the duct system should follow the guidelines outlined in "Industrial Ventilation"[2] with some consideration given to standard practices within the plastics industry. For instance, in most instances plastics fabricators use an elbow turning radius of 1½ times the diameter of the duct rather than two times the diameter as recommended in "Industrial Ventilation."[2] This practice is merely a compromise between static pressure loss and initial cost of materials.

Fans

The exhaust fan is the heart of any exhaust system. Without the fan providing the necessary suction and the necessary air movement through the hoods, duct system, scrubber, and stack, there can be no exhaust system.

The exhaust fan should be sized to handle the full exhaust volume at the static pressure for which the system is designed. Since metal-finishing installations traditionally are modified over the years, it is suggested that the fan selected be of such a size that additional capacity can be added at a future date by changing the motor and drive arrangement.

The fan manufacturer should be consulted to make certain that the fan selected is at the "midpoint" of the performance range for the particular fan size. The design engineer should make certain that the fan is constructed so that this additional capacity can actually be realized at a future date. He should beware of furnishing a class I fan when an increase in cubic feet per minute or slight change in the static pressure would require class II construction. This warning also applies to the differential between class II and class III, especially where metal fans are involved. In some cases, solid plastic fans have similar restrictions, and care must be exercised in making these selections.[3]

In any metal-finishing ventilation system, it is advisable to make certain that the fan is completely corrosion resistant on the inside as well as the outside of the fan itself. That corrosion of the exterior housing surfaces of a fan can lead to premature failure of the fan when the interior has an expensive corrosion-resistant system is humorous but sometimes all too true, and is unnecessarily expensive.

The most critical part of the fan is the impeller itself. It is important to make certain that the impeller is of adequate design and structurally strong to handle any increase in capacity at any future date.

The impeller should be constructed of materials that are completely corrosion resistant to the expected fumes that the fan will handle. If the fan is supplied with a coated impeller, it should be specified that the coating installer must spark-test this fan after it has been balanced. If the coating so applied is a thermoplastic coating, this coating should be supplied in adequate thickness for the corrosion protection involved. Particular attention should be given to the tip speed of the impeller. It is important to make certain that the centrifugal forces do not exceed the bond strength of the coating material, causing the coating to fling off and fail prematurely.

If the fan impeller is constructed of a thermosetting fiberglass-reinforced polyester, then it is important that it is in fact solid plastic construction and that it is built of the same resin as the remainder of the duct system. Again, particular care should be taken to insure that the resin selected has adequate corrosion resistance to all the contaminants the fan is expected to handle.

Construction of the fan should include an inspection door and housing drain. The housing drain helps to insure adequate drainage of the condensation caused by the natural centrifugal force of the fan impeller rotating within the housing. Since in many cases the exhaust stream coming from the metal-finishing operation is saturated heavily with liquid droplets, the liquids can be expected to build up within the fan housing very rapidly. Therefore, a drain should always be used on any fan involved on a metal-finishing application. This drain should be connected to a seal leg so that it can drain away the liquid properly without having to overcome the negative static pressure that may be encountered on the inlet side of the fan. An access door on the side of the fan housing should be provided so tnat inspection of the fan impeller can be accomplished with minimum difficulty. This access also permits cleaning of the fan impeller by washing or similar action. Cleaning of the fan impeller will help to extend the service life of the fan itself.

After the fan impeller, the fan housing is the next most critical item to which attention should be paid. The interior of the fan housing should be coated with the same material as the fan impeller. If all internal surfaces are coated as mentioned earlier, it is recommended that the exterior of the fan be provided with some type of corrosion protection as well.

If the fan housing is of steel to which a coating will be applied, then it should be so constructed that the coating can be applied with integrity. This means that all welds should be ground smooth with a slight radius in all corners. (Note that a steel impeller must have similar preparation.) All coatings should be spark tested after they are applied to the fan housing, and the coating should be carried through to the outside of all flanges and should overlap the edges of all corners.

If the fan housing is solid plastic, then it should be stiffened adequately to withstand the negative static pressures that may be encountered during normal operation or at some future date.

In addition to the foregoing considerations, both the fan housing and impeller should be constructed of materials that are basically fire retardant. In the remote event of a fire occurring in the ventilation system, the fan should be kept on to remove the smoke and fumes from the burning area through the exhaust system to the outside of the building. Smoke damage within the building itself sometimes can be more costly than the fire damage to a localized area of the exhaust system.

There are several additional accessory items that should be provided to facilitate installation and operation of the fan. One such item is the flexible connector used to connect the ductwork to the inlet and discharge sides of the fan, isolating the fan from the remainder of the duct system. Use of these connectors tends to reduce the sound transmitted by the fan to the entire ventilation system, and also will reduce any vibration that the fan may transmit to the duct system.

Another additional accessory item used with fans should be the vibration isolator. Depending on the location of fan mounting and the type of mounting supports, vibration isolators definitely

should be included in all fan installations. This accessory serves the same function as the flexible connector; that is, it tends to reduce the transmission of noise and vibration from the fan to surrounding systems.

Drains

In conjunction with the exhaust system and fan, condensate drains have been mentioned. It should be pointed out that these condensate drains should be connected to the waste-treatment area. These drains are a potential source of toxic contaminants, and special provisions should be made to connect these drain systems to prevent contaminants from entering the normal sanitary-drain system or storm-water system. Note that some hoods are also provided with condensate drains. These drains should be connected to a seal leg or capped for periodic drainage. This effort will prevent exhaust air from being drawn into the drain and reducing the effectiveness of the hood. These drains also should be connected to the metal-finishing waste-treatment system.

AIR-POLLUTION CONTROL DEVICES

Introduction

Metal-finishing operations that are carried on within liquid tanks create in general two different types of emissions; that is to say, emissions of a gaseous nature, and emissions of entrained liquid particulate. In very rare instances, mists are formed, but these occurrences are so infrequent that they will not be a subject of discussion in this paper.

Gaseous contaminants can be defined as those specific contaminants composed of gas molecules that are controlled by their brownian movement and are generally in the range of less than 0.01 micron in particle size.

Entrained liquid particles are contaminants that are released from a bath due to air agitation, drippage, mechanical agitation, and so forth, and that are generally 10 microns in size and larger.

A micron is defined as one-millionth of a meter, which is equivalent to roughly one twenty-five thousandth of an inch. For reference purposes, it should be noted that the smallest individual particle that can be detected with the naked eye has been reported to be between 60 and 100 microns in size. The average human adult red blood cell is 7.5 ± 0.3 microns in particle size. Tobacco smoke generally is defined as composed of solid particles that range from 0.01 micron to 1 micron in particle size. These points of comparison would give the metal-finishing operator some appreciation of the size of the particles with which he is dealing.

The amount of air-pollution-control equipment required and the efficiency with which this equipment must work will be dictated by local, State, and Federal Environmental Protection Agency (EPA) regulations. Due to the nature of the specific contaminants and the myriad of possible chemicals involved in metal-finishing operations, however, the present regulations are not specific enough to permit a discussion in this paper of the maximum emission levels for individual chemicals. In some cases, emission levels are specified as a maximum rate per pound of work processed. In other cases, there is no specific mention of any of the normal contaminants found in a metal-finishing operation. Some States do have emission regulations for such items as hydrogen fluoride, sulfuric acid, and hydrochloric acid, where a large segment of the State industrial complex handles such items.

There is a trend by the EPA to spell out, in some detail, limitations on specific contaminants. It is expected that such limitations will be established in detail for the metal-finishing industry in the very near future. In the meantime some companies, in an effort to anticipate tentative goals, have established that the scrubber or pollution-control device they install shall have an outlet concentration of contaminants that does not exceed the TLV.

There have been specific cases in the past where metal finishers have been subjected to the "nuisance" clause. The nuisance clause usually is included in most regulations; it is included specifically so that no industry or company can interfere with the right of any individual to the pursuit of his happiness and well-being or cause a nuisance that interferes with that basic right. There have been specific cases where metal finishers have chromic acid emissions that have caused damage to nearby property and houses. These cases have forced the particular company involved to make restitution for this damage. Subsequently, the company involved has been obligated to install pollution-control equipment that will remove specifically all the chromic acid contaminants passing through the system. There have been other similar cases involving other types of contaminants, but it should be noted here that proper planning and care in the design of the exhaust system as well as in the selection of the air-poilution-control device will preclude such instances.

As mentioned earlier, because of the fact that most contaminants coming from a metal-finishing operation are either gaseous or entrained liquid particulate in nature, wet scrubbers generally have been used for this type of operation.[4] Wet scrubbers are considered to be a chemical type of pollution-control device (as opposed to a mechanical or electrical device).

A packed tower generally is recommended for control of gaseous contaminants. There are some scrubbers on the market that do provide a limited amount of gas absorption through some other means other than a packed bed. The amount of absorption provided is limited, however, and if the objective is to reach the TLV on the discharge side of the wet scrubber, then a packed-tower absorption device definitely will be required. The packed-tower scrubber generally uses a recirculation system to recirculate the absorbing liquid through and across the packed bed. There are several different geometric modes of configuration for a packed tower. The geometric mode concerns itself with the manner in which the liquid comes in contact with the gas. In a countercurrent packed column, the liquid enters the top of the column and flows countercurrent to the gas stream, which enters the bottom of the packed column. In a crossflow packed column, the gas flows horizontally through a packed bed; the liquid flows from the top of the packed bed down to the bottom of the packed bed and discharges at the bottom while the gas discharges through the rear of the packed bed (see figs. II-1 and II-2).

For liquid-entrainment removal, wet scrubbers of various designs have been employed effectively to obtain efficiencies in the range of 99 percent removal or more. The nature of the liquid entrainment coming from the metal-finishing operation must be studied carefully. If the tank is at room temperature, the entrainment generally will be relatively large, that is, probably 100 microns or larger. For this particular type of liquid entrainment, a simple air washer, which is essentially an entrainment-removal device with a washing action to keep the concentration of the contaminants to a minimum, is all that is required. If the tank is heated, however, there is some concern that smaller particles will be generated. In this particular case, the air washer or entrainment separator should be selected with care, since there is a possibility that liquid particulate matter as small as 10 microns in size can be emitted.[5]

In the case of chromic acid fumes, it is important to remember that even a very small particulate droplet of chromic acid can cause damage to painted surfaces. For this reason, an entrainment-removal device that is efficient down to the range of 3-5 microns generally is recommended.

Recovery of Contaminants

There have been many installations where the recovery of contaminants from a metal-finishing operation has proven to be economical. In general, in order to recover the contaminants economically, the water used for washing and dilution must be evaporated to increase the concentration of the contaminant to a level where it can be reused back into the metal-finishing process.

An evaporator, using a supply of heated water, generally is recommended for such applications as nickel-plating and chrome-plating operations where recovery can be economical. Table II-1 shows the results of such an evaporator design and indicates the approximate range of inlet concentrations over which an evaporator can be economically effective.

There are many cases where an evaporator can be combined effectively with a wet scrubber. That is, the wet scrubber serves a dual function—removal as well as recovery of contaminants. In order to accomplish this function effectively, additional equipment must be provided. This additional equipment involves a heat exchanger and extra piping, as well as arrangements to run a batch operation through the evaporator/wet-scrubber system. In this particular case, the scrubbing liquid is heated to a point where water is evaporated from the airstream while the contaminant is being removed within the packed bed.

There are some cases where a separate evaporation system can be justified economically. A separate evaporation system will be employed where a number of small scrubbing installations are handled separately, and the liquid from each of these is fed to a single evaporator system.

Water Consumption

A wet scrubber, to be efficient, *must* raise the relative humidity of the exiting air to the saturation level. Since the relative humidity on the inlet side of the scrubber is generally less than the saturation level, evaporation of water takes place within the scrubber itself. For this reason, a makeup supply of some type of relatively "fresh" water must be added to the scrubber recirculation system. The amount of water used as makeup must be greater than the evaporative losses that can be expected within the scrubber itself.

If the contaminant being removed is of a gaseous nature, then the amount of fresh water added to the system must be of sufficient quantity and quality to permit the recirculation solution to be kept well below the level at which the concentration of the contaminant in the liquid phase does not interfere with the gas absorption rate. For most metal-finishing operations, this amounts to a make-up rate of approximately 5-10 percent of the total amount being recirculated in the scrubber system.

In addition to the above considerations, it may be necessary to consider maintaining the concentration of the contaminant in the overflow of the scrubber in the range where it can be handled effectively by the wastewater-treatment system that has been installed.

Since the overall consumption of water for any metal-finishing operation is limited in order to keep the capital investment of the wastewater-treatment system to a minimum, the source of fresh water for the scrubbing system should be studied carefully. While it is best to use fresh city water for the scrubbing solution, in some cases the fresh water can be the clarified water from the waste-treatment system. That is, the treated water from the waste-treatment system could be returned to the scrubbers as the fresh-water supply, leading to recycling of the stream. This recycling will tend to reduce the amount of city water being used in the system.

In addition to the foregoing arrangement, there are other arrangements where the rinse water from the secondary or tertiary rinse tank can be used as the fresh-water makeup for the scrubber.

Table II-1.—*Typical operating data for chrome- and nickel-plating evaporator/scrubber systems*

Recovery data	Average value over test period	
	Chrome	Nickel
Parameter:		
Inlet air:		
Rate, CFM	10,000	10,000
Temperature/relative humidity	77° F/40%	77° F/40%
Steam use, pounds per minute at 25 psi	120	120
Total electrical use, amperes at 440 V	200	200
Recycle rate, gallons per minute	225	225
Heat exchanger temperature	150°-155° F	150°-155° F
Reservoir temperature	114° F	114° F
Evaporation rate, gallons per minute	9.5	9.5
Return rate to tank, gallons per minute	1.5	1.5
Output air:		
Temperature	131° F	131° F
Relative humidity	100%	100%
Hourly reclaim rate, pounds per hour expressed as chrome or nickel solution	215	83

Operating costs

	Dollars per hour	
Item:		
Electrical, at 1.5 cents per kW-h	0.35	0.35
Steam, at $1.50 per 1,000 pounds	10.75	10.75
Total cost per hour	11.10	11.10
Reclaim cost per pound CrO_3	.052	.134
Original chrome cost per pound	.50	1.50

Note.—Based on actual case study using countercurrent-flow packed-bed scrubber, containing 4 feet of 1-inch Tellerettes.

The concentration of the contaminants in the fresh-water makeup to the scrubber must be kept to a sufficiently low value to preclude any release of the contaminants to the airstream in the scrubber itself. In some cases, even the primary rinse tank may have a sufficiently low concentration to permit using this water as the makeup water to the scrubber.

As a further water-conservation practice, there have been cases where the overflow from the scrubber has been used as makeup for a primary rinse tank. This practice would be especially beneficial when more than one rinse tank is employed in a process.

The exact nature of the supply of fresh-water makeup for a scrubber system can only be determined upon detailed examination of the specific application. Each application must be weighed carefully with all the alternatives previously mentioned carefully considered, and the final selection must be based on the merits of the case in point.

With the recirculation piping, drainline piping, and other piping connections on the scrubber, care should be taken that all of these are connected to the wastewater-treatment system.

Costs

Table II-2 illustrates typical costs for the installation of ventilation and air-pollution-control equipment for some typical metal-finishing operations.

The number of tanks being exhausted, as well as exhaust rate, together with the size of the individual equipment selected, will control the actual installation and operating costs.

Care should be exercised in the selection of the air-pollution-control equipment so that the operating cost is not excessive. It is important to remember that, as a rule of thumb, the operating costs of each motor used on the ventilation and air-pollution-control system will range from $50 to $100 per brake horsepower per year, depending on local electrical costs. On a large system, this cost can mount up quickly to a point where the savings of several inches of static pressure of resistance within the system by careful selection of the pollution-control equipment and design of the ventilation system can save many thousands of dollars of operating costs in a year's time.

Other Considerations

In appendix B of this paper are some examples of ventilation systems employing air-pollution-control devices that have been installed in metal-finishing operations at various locations throughout the country.

In addition to the design considerations listed earlier, there are several items that should be mentioned in the ventilation of metal-finishing operations. These items should be taken into account on any installation.

If the metal-finishing operation includes cyanide salts as one type of metal-finishing solution and the cyanide tanks must be exhausted, then the exhaust system for the cyanide solutions should be kept separate from any exhaust system that incorporates acid solutions. This practice will preclude the formation of any hydrogen cyanide within the exhaust system itself, which could lead to potential problems.

Normally, if there are alkali solutions containing no cyanide salts that must be exhausted, they can be introduced into an exhaust system handling acid solutions so that some neutralization can be effected within the duct system before reaching the scrubber. This practice will serve to

Table II-2.—*Typical costs of ventilation system*

Metal-finishing operation	Type of scrubber	Pressure drop		Liquid rate of scrubber recirculated[1]	Horsepower		First cost of scrubber, approximate	Annual power cost[4]	Total installed cost, complete system
		Of scrubber	Total		Pump[2]	Fan[3]			
		Inches	*Inches*	*gpm*			*Dollars*	*Dollars*	*Dollars*
Chrome	Countercurrent	2	4.5	120	0.7	12.8	6,000	1,490	12,000
Nickel	Air washer	1	3.5	60	.4	9.4	3,500	837	9,000
Zinc	Crossflow	1.5	4.0	60	.4	11.5	7,000	1,024	13,000
Phosphate coat	Air washer	.7	3.2	50	.3	9.1	3,000	810	8,000

[1]Fresh makeup rate will be from 5 to 10 percent of figure shown, but no less than 3 gpm.

[2]$\text{Pump hp} = \frac{8.33\ H\ s\ (gpm)}{33000\ (50\%\ eff)}$.

[3]$\text{Fan hp} = \frac{.000157\ Q\ (\text{includes w.c.})}{55\%\ eff}$.

[4]Operating cost = hr (hp) (.746) (1.5).

Note.—Basis of comparison: 10,000 CFM for all systems; static pressure loss in all air-handling systems exclusive of scrubber is 2.5 inches water gage; fan efficiency, 55 percent; pump efficiency, 50 percent; annual operating days, 300; power cost, 1.5 cents per kilowatt-hour; all scrubbers 95 percent efficient or better.

reduce the load of acid contaminants entering the waste-water-treatment system. This step should not be taken, however, if recovery of the acid contaminants is being attempted.

There are some metal-finishing operations that use an ammonium-based alkali within the tank system. Any exhaust system that is venting an ammonia tank should be kept separate from an exhaust system that is handling hydrochloric acid. The combination of ammonia and hydrochloric acid in an exhaust system forms the compound ammonium chloride (NH_4Cl). Ammonium chloride, when it is formed, becomes a submicron particulate matter that is impossible to remove in any of the wet scrubbers discussed in this presentation. Ammonium chloride can appear as a dense white cloud that can lead to serious problems. The metal-finishing operator who has an ammonium chloride effluent may find himself faced with complaints from local citizens due to the reduced visibility in the plant area. The simple expedient of separating these two exhaust streams internally, making certain that the hydrochloric acid vapors are removed to a high efficiency, and then separating the exhaust points of the two by as wide a distance as possible will help to preclude this possibility.

CONCLUSION

The design of a ventilation system for metal-finishing operation should be based on OSHA considerations within the building. The specific manner in which the exhaust fumes are contained within the area and removed through the exhaust system should be studied carefully so that the contaminants are kept within a confined area. The flow of fresh air should be constant past all work stations so that the TLV of the contaminants is not exceeded.

The exhaust system should be designed so that it uses a minimum of static pressure resistance to keep the operating costs down. Materials of construction used should have corrosion-resistant characteristics combined with fire-retardant characteristics so that the effectiveness of the exhaust system does not deteriorate with age.

The fan and the pollution-control device selected should be constructed of similar corrosion-resistant and fire-retardant materials. The air-pollution-control device selected should be efficient enough to allow operation under existing codes. Some provisions can be made in many scrubber designs to increase the efficiency at a later date. Care must be used in this selection, however, so that the fan capacity can be increased at slight additional costs at some future date.

All condensate drains and drainline connections to the wet scrubber should be directed to the waste-treatment system to prevent contamination of ground water, sanitary, or storm-sewer effluents.

Careful consideration of the fresh-water makeup to the wet-scrubber system should be included in the overall planning of the wastewater-treatment system.

A detailed evaluation of any vendor's proposal for the complete exhaust system and/or pollution-control devices should include the major points covered in this paper.

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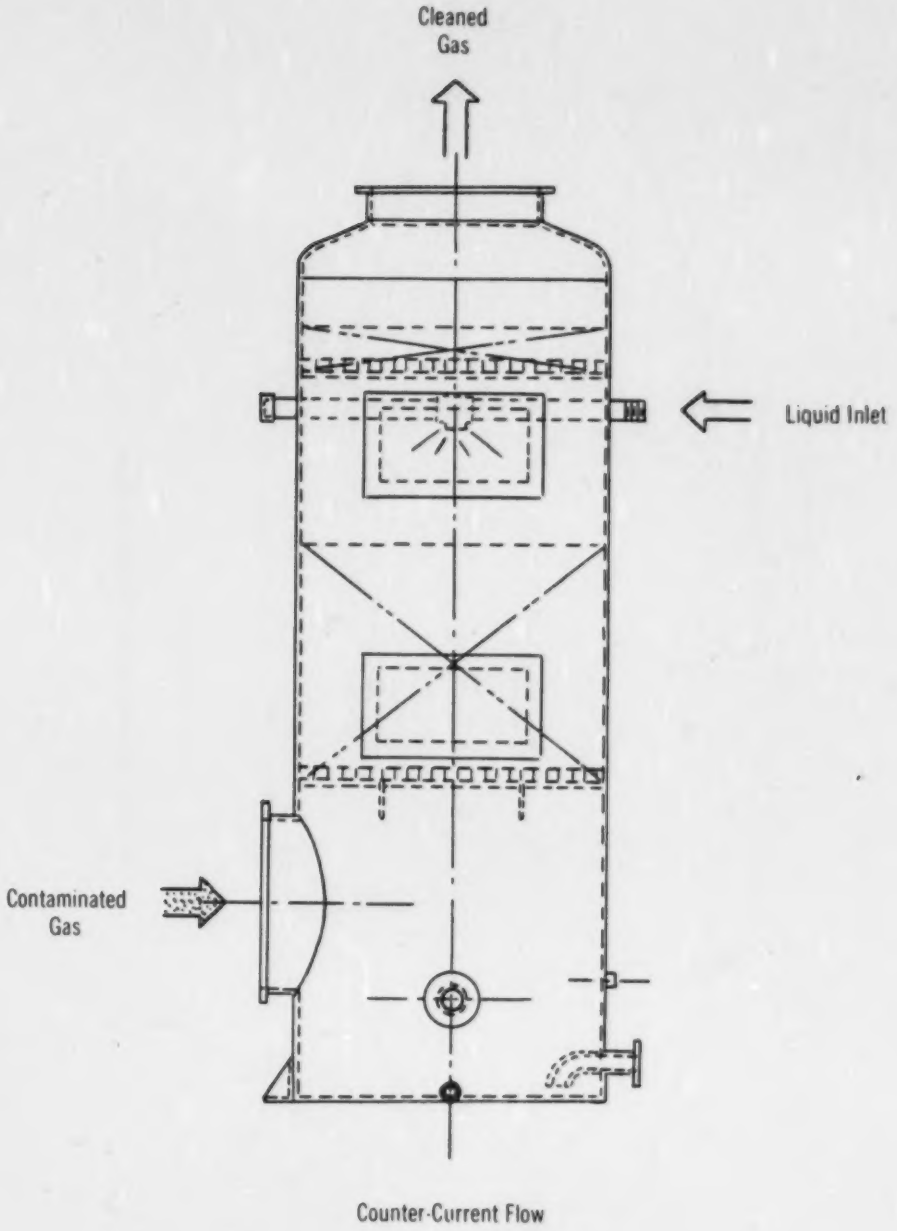


Figure II-1. Countercurrent packed-bed scrubber.

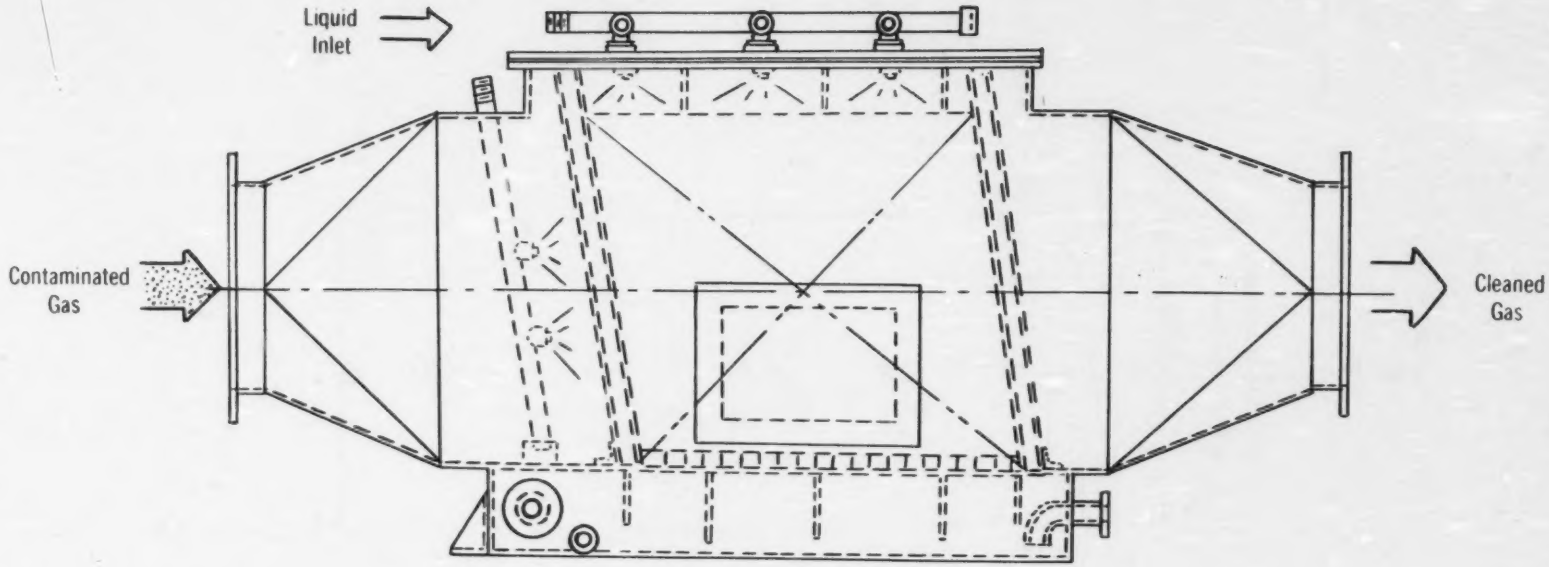


Figure II-2. Crossflow packed-column scrubber.

Chapter III

CORROSION PROTECTION OF FLOORS AND EQUIPMENT

FLOOR PROTECTION

In the consideration of any wastewater system, some means of surface protection of the floor area around the tanks is always included. Surface protection of the floor is required to protect the substrate (actual floor material) from damage due to spills, splash, drippage, overflow, or catastrophe. In the event of a catastrophe, it is imperative that the liquids involved all be contained within the area serviced by the wastewater-treatment system provided. Depending on the specific design used and the extent of the catastrophe, spill, or other problem, the liquids involved may have to be contained within this area for from several minutes to several hours. Obviously, the liquids could cause severe damage to the substrate and even the building and/or building foundation if the area is not properly protected.

The type of material selected for this service should be based on the following considerations:

- Substrate material
- Type of traffic, if any, that will be using this floor area
- Broad-range corrosion resistance
- First cost
- Ease of installation and its cost
- Repairability

There are many different types of materials available on the market. Most of these materials are considered to be monolithics and are based on the use of a thermosetting resin. Thermosetting resins are those resins using a catalyst system. They start off at room temperature as a liquid to which the catalyst is added and, depending upon the amount of catalyst and the temperature and humidity, the resin "sets up" or becomes a solid with an exothermic reaction within from 5 minutes to several hours. Once this exothermic reaction is complete and the heat has dissipated, the resin is fully cured and usually can be treated in the same manner as the substrate. The complete cure may be complete within several hours, but most materials should not be subjected to anything other than foot traffic for from 24 to 48 hours after being fully installed. Thermosetting resins include epoxies, polyesters, and furans, although most floor-protection materials are based on either epoxies or polyester resins.

It is imperative to point out that there are probably well over 100 different epoxy resins available, as well as over 500 different polyesters. However, limiting the materials to the foregoing considerations probably will reduce these numbers to 20 and 100, respectively, for epoxies and polyesters. With this variety still available, the ideal material should be selected based on the following parameters:

- Corrosion resistance to a wide range of acids and alkalis
- Low first cost and installation cost
- High resistance to impact damage
- High bond strength to substrate
- Visual-inspection capability and ease of repair

The only other consideration is the amount of traffic or type of load to which the material will be subjected. In some cases, the materials are applied using nothing more than an aggregate or other type of filler. The aggregate is used to enhance impact strength and thermal expansion characteristics, and to provide additional thickness of material. In other cases, the same materials or slightly different formulations are used in conjunction with some type of additional reinforcement, such as glass cloth.

Reinforcement with glass cloth markedly increases the impact strength of the material. It also enhances other properties that make this type of addition very valuable in many instances.

When taking all factors into consideration, a material that approaches the ideal would be a modified glass-reinforced polyester. This material has the following properties:

- It is corrosion resistant to the vast majority of plating solutions.
- It has a total installed cost of from $2 to $3 per square foot, which makes it economical.
- It bonds tenaciously to the substrate and discourages undercutting so that cracks and damage are contained within a localized area.
- The glass reinforcement provides high impact strength and permits the material to bridge minor shrinkage cracks in the substrate.
- Cracks, if they do occur, can be repaired readily by maintenance personnel with minimum training.
- Cure is complete within hours, so that downtime for repairs or interruption of initial construction can be held to minimum.
- The material can also be applied to vertical surfaces so that curbs and walls can be given the same corrosion protection. Thus, any chemicals involved in a catastrophic spill can be contained within the designated area serviced by the water-treatment system.

The best material selected for floor protection service is wasted if the proper consideration is not given to the overall design of the substrate, the method of installation of the material, and the surface preparation. Areas that warrant particular attention include floor drains, joints between walls and floors, and so forth. Illustrated here are the methods that are used generally to handle these potential trouble areas.

Note that before the installation of any monolithic material the substrate must have the surface preparation recommended by the manufacturer. For most monolithics, when concrete is the substrate, the surface preparation is generally a steel-trowel finish followed by acid etching of the fully cured concrete.

PROTECTION OF EQUIPMENT

In addition to protection of the floor under the tanks, consideration should also be given to protection of other areas. Whenever corrosive chemicals are used, all equipment exposed to the same atmosphere or in direct contact with the chemicals is subjected to rapid degradation. Equipment and areas in this category include the following:

- The exterior of the tanks
- All surfaces of a plating machine
- Structural steel used anywhere in the vicinity of the corrosive chemicals
- Utility connections or pipelines that are located within the area where floor protection is provided

Equipment installed in a metal-finishing operation is expensive to replace. It is also extremely expensive if the equipment must be repaired constantly.

One of the best questions that is always asked in conjunction with any discussion of catastrophes in a plating area is, "How could they occur?" There is probably no better response or more likely occurrence than "through the forces of corrosion and neglect." Therefore, it is economic folly when considering floor protection not to investigate the possibility of providing similar protection to *all* equipment contained within the floor area that will be protected.

With the normal maintenance that will be required by the treatment plant and equipment, as well as by the plating equipment itself, corrosion protection of tanks, machinery, and structural steel will reduce maintenance on these items, freeing personnel to maintain critical equipment. It will also lessen materially the chances of a catastrophic event.

Corrosion protection for these parts and areas can be provided by coatings that are applied readily by brush or spray and that have the same properties and corrosion resistance as the monolithics used on the floor.

Typical of such materials is a flake-reinforced polyester. This material is available in the same grades as the monolithics and can be applied to a thickness of from 15 to 30 mils at a nominal cost. The typical installation will range from 80 cents to $1.50 per square foot, depending on the amount of surface area being covered and the complexity of shape. This means that the material is competi tive with most epoxy, vinyl, or similar paint systems used as coatings. The advantage of this type of coating is its superior impact resistance, better thermal-shock resistance, lower expansion coefficient, and resistance to undercutting.

The coatings mentioned here have been field proven in years of trouble-free service, where they have eliminated the usual annual reapplication of materials that is normal with most paint systems in corrosive areas. They are also readily cleaned with a water flush and could even be brushed with a stiff bristle brush without fear of damage.

OTHER CONSIDERATIONS

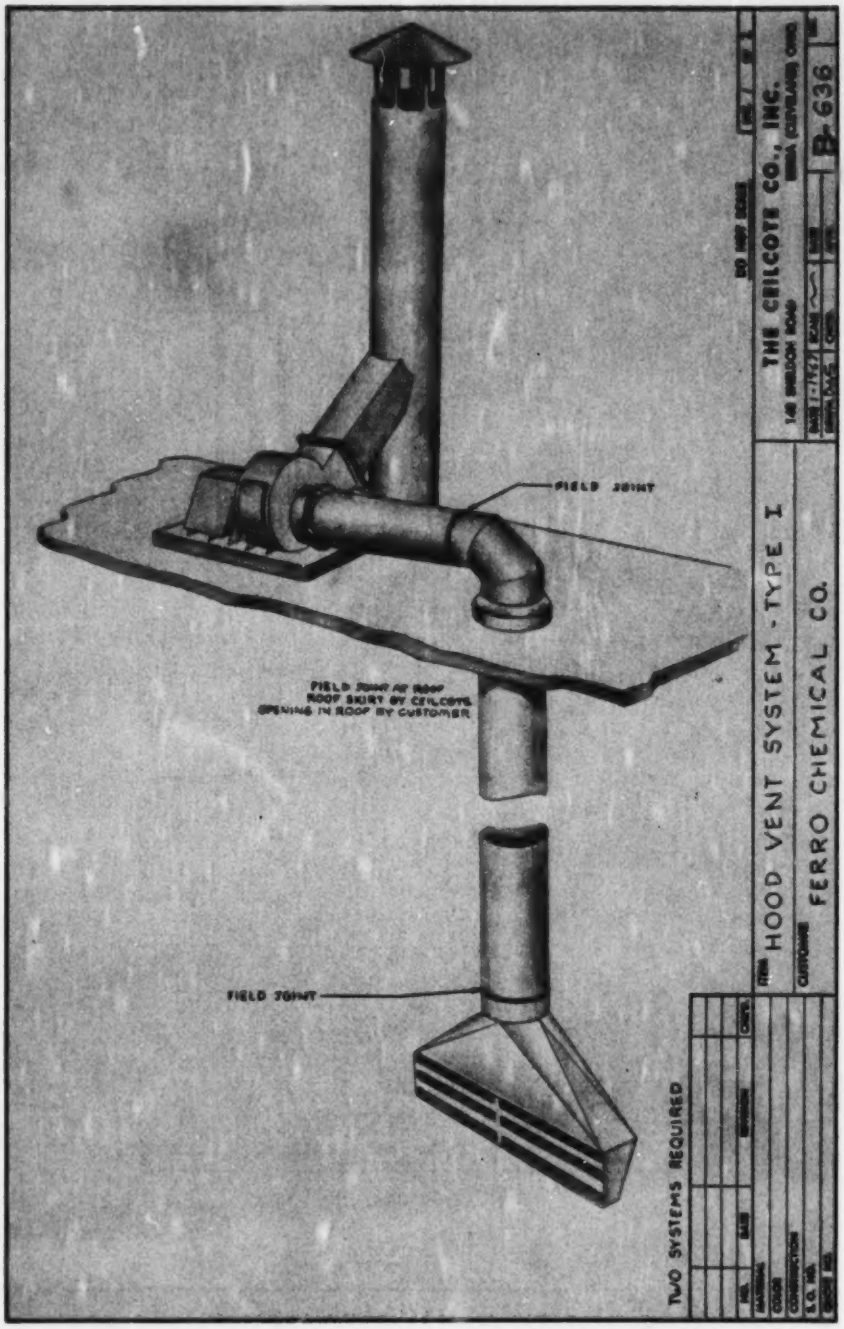
It is obvious that the area occupied by the waste-water treatment should receive the same considerations. Although the function here is one of neutralization of corrosives, it should also be realized that the same types of spills, leaks, splash, and other minor occurrences could cause serious damage to floors, tank exteriors, structural work, and so forth.

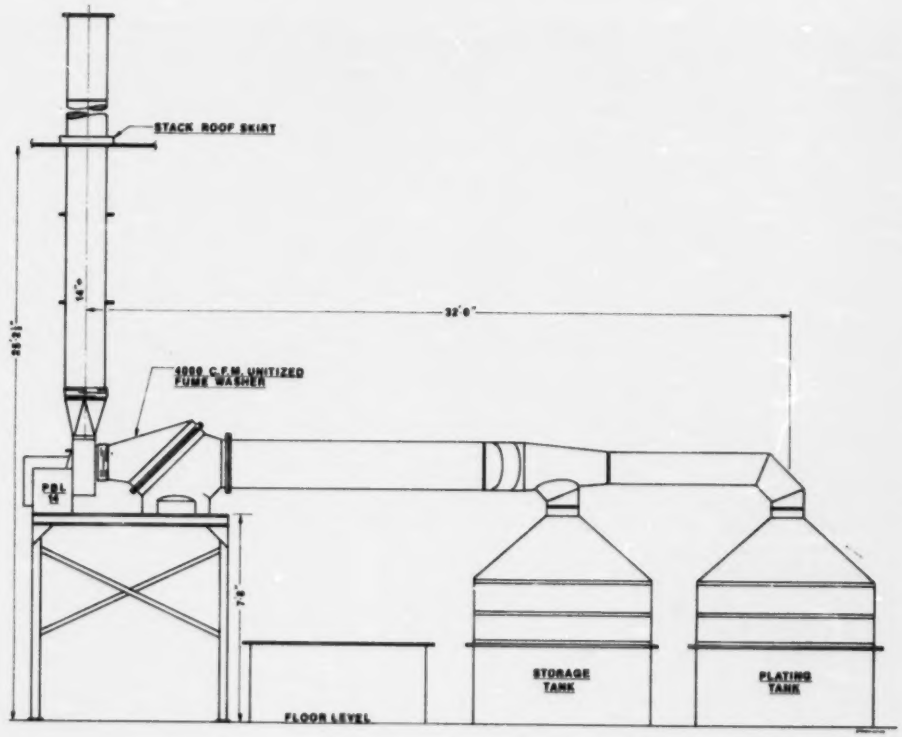
In addition, serious consideration should be given to the manner and means in which the liquid effluent from the metal-finishing area is transported to the treatment plant. Pipelines must be installed properly and completely corrosion resistant, both inside and out. Trenches, if used, should be protected similarly.

In all cases, wherever corrosive chemicals are used within the plant, careful attention should be given to corrosion protection of all surfaces in those areas where the chemicals are received, stored, consumed, and transported to the waste-treatment plant, and where they are finally neutralized.

Appendix A

EXAMPLES OF VENTILATION SYSTEMS USING AIR-POLLUTION-CONTROL DEVICES





REV.	DATE	DESCRIPTION	BY / CHKD

CUST. DWG. No. | SCALE

OPERATING CONDITIONS

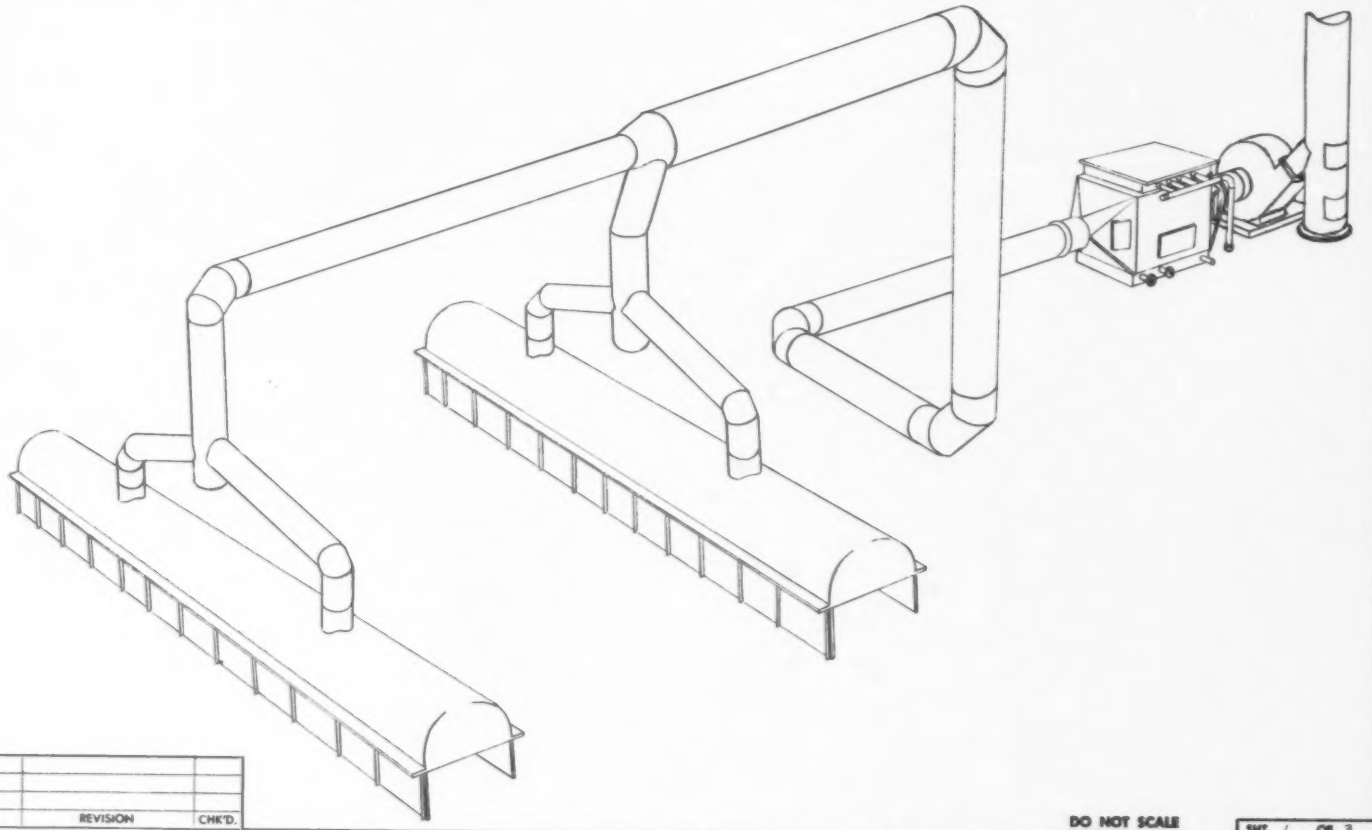
PRESSURE-DESIGN	PRESSURE-OPERATING
TEST	SPEC.
MATERIAL	COLOR
CONSTRUCTION	

TITLE

CUSTOMER

THE CEILCOTE CO., INC.
140 SHELDON RD. BEREA (CLEVELAND), OHIO

QUOTE No.	S. O.	SHT.	OF
DRAWN	CHK'D.	APPR.	C-
DATE	DATE	DATE	REV.



NO.	DATE	REVISION	CHK'D.

MATERIAL
COLOR
CONSTRUCTION
S. O. NO.
QUOTE NO.

ITEM DURACOR VENTILATION SYSTEM

CUSTOMER ARMCO STEEL CO.

DO NOT SCALE

SHT. 1 OF 3

THE CEILCOTE CO., INC.
140 SHELDON ROAD BEREA (CLEVELAND) OHIO

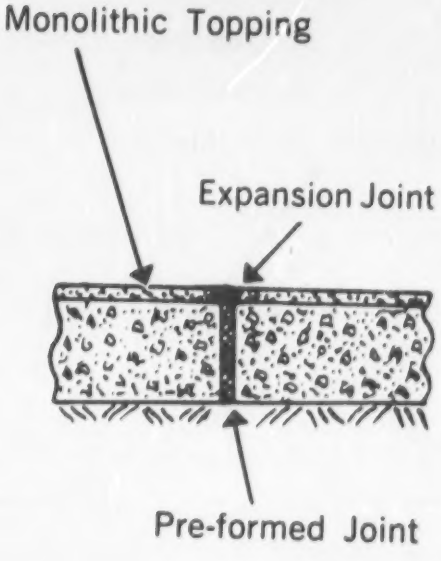
DATE 4-25-67	SCALE ———	DATE	B-	REV.
DRWN. DWS	CHK'D.	APPR.		

Appendix B

EXAMPLES OF FLOOR PROTECTION COATING APPLICATIONS

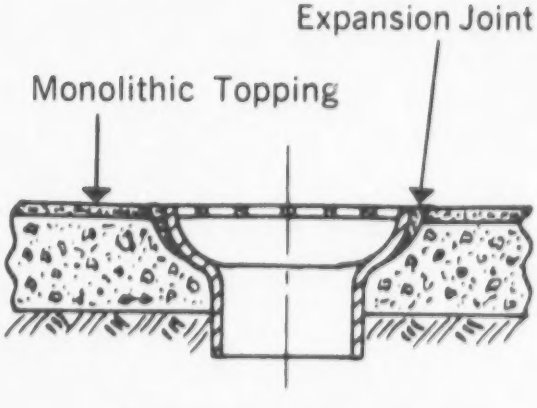
Expansion Joints

for monolithic floor



Drains

for monolithic floor



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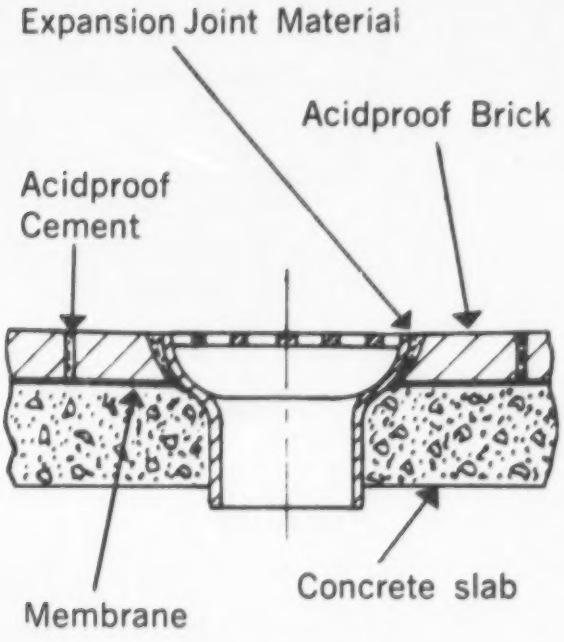
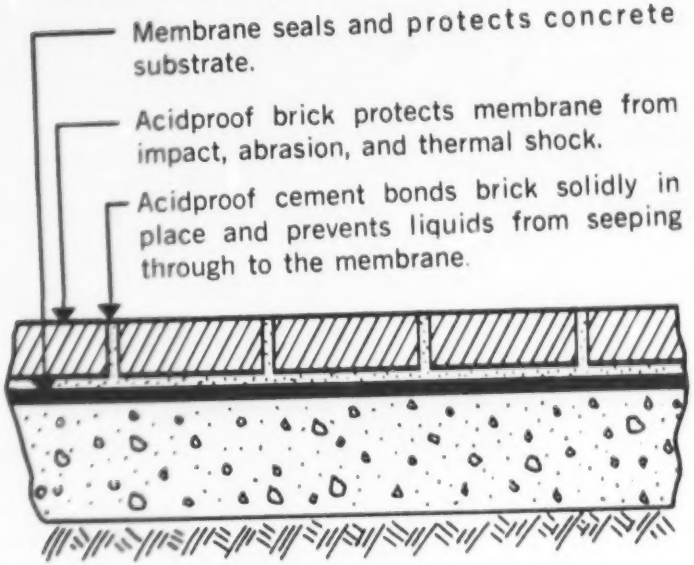
Drains

for brick floor

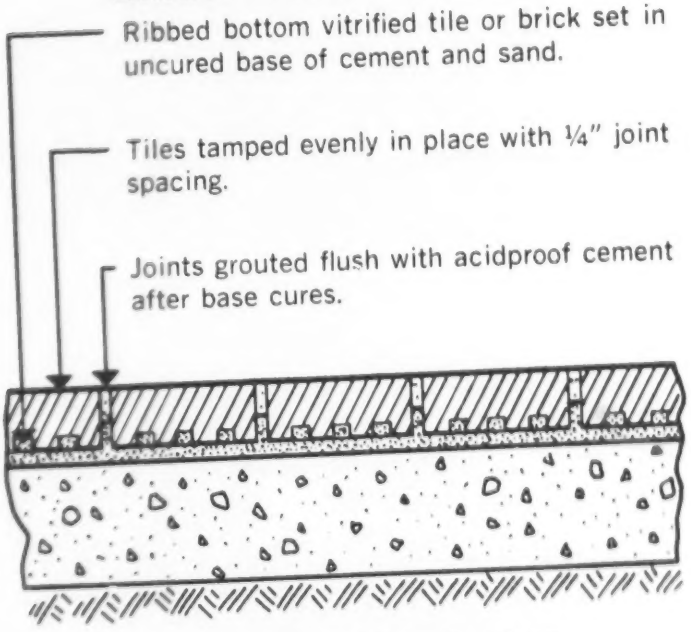


ACIDPROOF BRICK & MEMBRANE CONSTRUCTION


Membrane seals and protects concrete substrate.
Acidproof brick protects membrane from impact, abrasion, and thermal shock.
Acidproof cement bonds brick solidly in place and prevents liquids from seeping through to the membrane.

Acidproof Membrane, Brick & Cement Construction

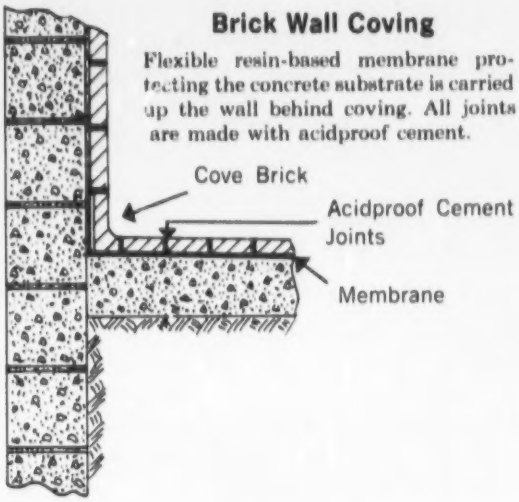
GROUTED BRICK CONSTRUCTION


Ribbed bottom vitrified tile or brick set in uncured base of cement and sand.
Tiles tamped evenly in place with ¼" joint spacing.
Joints grouted flush with acidproof cement after base cures.

Grouted Brick Construction

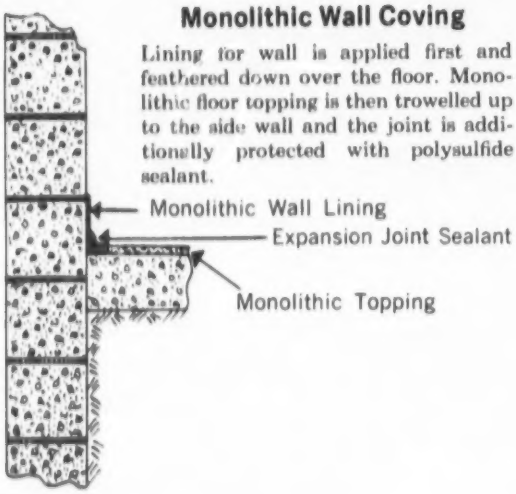
Brick Wall Coving

Flexible resin-based membrane protecting the concrete substrate is carried up the wall behind coving. All joints are made with acidproof cement.



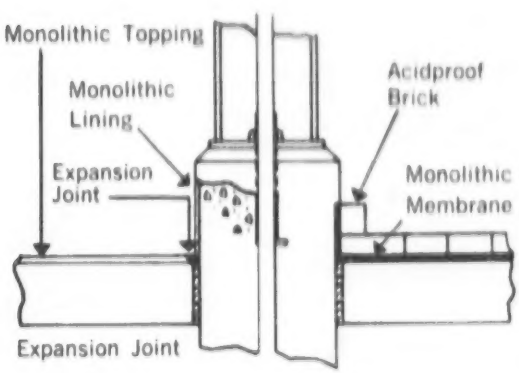
Monolithic Wall Coving

Lining for wall is applied first and feathered down over the floor. Monolithic floor topping is then trowelled up to the side wall and the joint is additionally protected with polysulfide sealant.



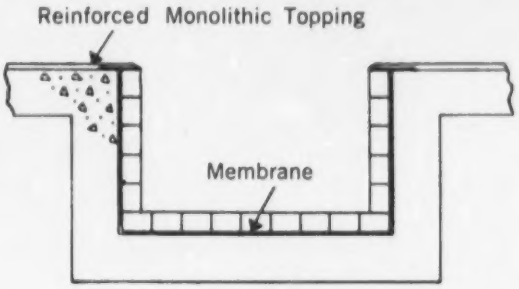
Brick & Monolithic Column Bases

Both types are treated essentially the same as sidewall covings for the respective materials.



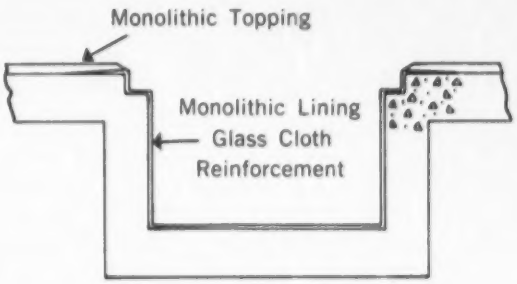
Monolithic Floor Combined With Acidproof Brick Trenches

Trench is lined with flexible membrane. Brick is then layed up with acidproof cement. Glass reinforced monolithic floor topping is trowelled across the header course to completely seal the joint between the concrete trench and its brick lining.



Monolithic Trenches

Consists of reinforced monolithic lining material specially formulated for vertical surfaces. Note that lining runs up on to the floor, and that the floor topping is brought to the edge of the trench to completely seal the monolithic joint.



Monolithic Pump Base

Top and sides of the base are covered with monolithic lining which is feathered over the floor. Monolithic floor topping is then trowelled on floor area and lapped up the side of the base. Use of reinforcement is determined by service conditions.